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1950 and All That

A Report* has just been published which gives statistics of iron foundries for the year 1950. It covers 908 foundries and specifically excludes firms employing fewer than ten men. Figures for Northern Ireland are included with England, as separation would possibly disclose private information. As there are about double this number making iron castings, there must be many shops excluded perhaps because they are departments of engineering concerns and the like. For instance, whilst the employment figure was returned in the Census as 124,185, the figures we published about that time were of the order of 146,000. Nevertheless, the figures disclosed are very impressive.

The total value of the sales of these concerns reached a total of £137,354,000. The corresponding figure for the iron and steel (melting and rolling) trade was £471,549,000, so that if the whole of the output of the foundry industry—that is, the steel, non-ferrous and light alloy—were aggregated, then it could be assumed that the total would equal if not exceed that of the steel industry. Another illuminating figure is the sum of money paid out for supplies. It amounted in 1950 to over £60,000,000, whilst £46,721,000 was paid out in wages. The value for each individual's output was not constant for England, Scotland, and Wales. England led with £614 for the year, Scotland was second with £547 and Wales last at £504. This must not be interpreted in terms of application to duty, because the value of the output obviously varies with the product manufactured.

Amongst other curious figures given is the number of working proprietors. This, we presume, means manually working, for conducting the affairs of an iron foundry is no "feather-bed" job. The number given at 165 is fewer than earlier figures reported under this heading. No doubt the filling up of forms is replacing the filling up of moulding boxes. Another interesting figure is that the industry paid out two thousand pounds to 29 outworkers. Would these be gardeners and the like? It is interesting to note that in the year covered by the Report, the employers' share of all National Insurance contributions was £1,238,000. A final figure is for work done on work given out; this amounted to £1,311,000, and we can only imagine it is for patternmaking, though at least one concern places all its fettling into the hands of an "outside" contractor. Another valuation, which to our mind is not realistic, is of stocks of finished goods at the beginning and end of the year. It rose from £7,905,000 to £8,530,000, as the paper value was increasing throughout the year. Numbers and weights are a truer barometer of real worth than constantly changing money values. Whilst the figures given are interesting, they lose some significance through the time lag between collection and publication.

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* Report on the Census of Production for 1950. Vol. 3, Metal Manufacture and Vehicles. Published by H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 2s. (See also page 273 of this issue.)

Engineering and Marine Exhibition

Countless castings will be on show among the stands of the Engineering, Marine and Welding Exhibition and the Chemical Plant Exhibition, to be held at Olympia, London, from September 3 to 17, where it will occupy more than a quarter million square feet. It will be open from 10 a.m. to 8 p.m. daily, excluding Sundays. For nearly fifty years this exhibition has been held in alternate years (apart from interruptions caused by the two world wars) and every fourth year a 1955.

During the run of the exhibition, some 70 trade and technical associations will pay official visits, those of the Institute of British Foundrymen and the Foundry Trades Equipment and Supplies Association being on September 7; the Worshipful Company of Founders on September 10; and the Institute of Vitreous Enamellers on September 16.

Notable Exhibits

Among approximately 500 stands many of the exhibits will be shown actually in operation, including Ruston & Hornsby's latest design of gas turbine which will run on load for 10 hrs. a day during the whole of the thirteen days' duration of the exhibition, and supply electricity for a considerable part of the lighting of the three main halls at Olympia.

A large, half-turbine-case casting, fully machined and weighing approximately 6½ tons will be on view at the stand of the David Brown Companies. John I. Thornycroft & Company, Limited, who are also exhibiting Diesel engines and models of boilers, will demonstrate the application and method of operation of liquid-fuel-burning equipment.

A number of companies will be exhibiting furnaces, including Barlow-Whitney, Limited, who will have amongst their exhibits high-temperature electric furnaces utilizing silicon carbide resistors for temperatures up to 1,400 deg. C., and Incandescent Heat Company, Limited, who manufacture many types of metallurgical furnaces.

Illustrating the mechanical-handling field, Ransomes, Sims & Jefferies, Limited, will show a number of fork-lift trucks; a new type of hydraulic jack may be seen on the stand of Tangyes, Limited, and an entirely new line to be shown by Felco Hoists, Limited, will be a rapid hoist incorporating a special overload feature. Lifting magnets will be included amongst the exhibits of Allen West & Company, Limited. Among pumps for a wide variety of applications which will be on show, G. & J. Weir, Limited, will be exhibiting a pump with a capacity of 2,700 gall. per hr., and industrial valves of Audley Engineering Company, Limited, and Newman, Hender & Company, Limited, will be featured, including networks of pipes and valves, known as Christmas trees and used for the controlling of the flow from oil wells. C. A. Parsons & Company, Limited, as well as exhibiting a completely bladed high-pressure rotor of a 60,000-kw. turbine, will be showing a number of transformer parts.

The whole field of welding will be covered in detail. The Butterley Company, Limited, will be showing, for the first time, a complete oxygen-generating plant suitable for installation in the oxygen-user's own works. Various types of non-destructive testing equipment will be seen at several stands; for example, Solus-Schall, Limited, will be giving working demonstrations of X-ray fluoroscopic inspection, ultrasonic flaw detection and automatic magnetic inspection; Newton Victor, Limited, will exhibit industrial X-ray equipment.

(*Concluded at the foot of column two*)

Electric and pneumatic tools, control and test equipment, as well as the stands of the research associations, and the wide range of auxiliary marine exhibits will also be centres of attraction for foundrymen visitors. Vitreous enamellers are well catered for in this year's Chemical Plant Exhibition, where corrosion-resistant linings and cements will be shown by a number of well-known firms, as will plant in enamelled cast iron and glass-lined steel. The chemical plant exhibition is sponsored by the British Chemical Plant Manufacturers' Association, which will have its own stand.

Conference Paper Authors

MR. JOSEPH TAYLOR, one of the joint Authors of the Paper "Difficulties in the Production of Centrifugally-cast Nickel-bronze Bearing Shells," printed in this issue, is technical superintendent at the David Brown Foundries Company. He was educated at the University of Sheffield and, after graduating, joined the staff of a steel company as a research metallurgist, subsequently becoming assistant to the chief metallurgist, prior to taking up his present appointment. He is a member of several professional associations, including the Institution of Mechanical Engineers and the Institute of Metals.

MR. ZYGMUNT STOKOWIEC, the second of the joint Authors of this Paper, joined the Institute of British Foundrymen in 1944. He was educated at Warsaw and Grenoble Universities, where he graduated in mechanical engineering in 1930. He has been employed as metallurgist and foundry manager in Poland, France and Great Britain. At present he is employed by the David Brown Foundries Company as bronze-foundry superintendent. He also is a member of several technical institutions, including the Institution of Mechanical Engineers and the Institute of Metals.

MR. RICHARD S. JACKSON, the third joint Author, was educated at the Sir John Cass Technical Institute, London, and the Royal School of Mines. After graduating as an B.SC. he joined the staff of the David Brown Foundries Company as a foundry metallurgist. His present position is investigator in the castings section of the British Non-Ferrous Metals Research Association.

Difficulties in the Production of Centrifugally-cast Nickel-bronze Bearing Shells*

By J. Taylor, Assoc.Met., F.I.M., A.I.Mech.E., Z. Stokowiec, F.I.M., M.I.Mech.E., and R. S. Jackson, B.Sc., A.R.S.M.

Shells for Babbitt-metal-faced Diesel-engine bearings are produced as castings in a leaded nickel-bronze alloy by the horizontal-axis centrifugal method. The occurrence of pinholes in the facing was traced to slight porosity in the base metal. During the metalling process, gases, whether trapped in the pores or derived from the flux, form bubbles in the Babbitt metal which on subsequent machining to the finished size, leave depressions in the surface. It is believed that this inter-dendritic porosity in the backing metal is due to gas evolution in the later stages of the solidification of the copper/nickel/tin matrix and that this gas forces the lead, which is still liquid, out of the regions in which the evolution occurs. Methods of preventing the original solution of the gases included avoidance of the use of gassy ingots; the addition of small quantities of titanium; melting under an oxidizing flux and inert-gas scavenging of the molten metal, but all these methods proved unsuccessful. Other modifications to the process, including changes in the pouring temperature and speed of rotation of the casting machines had little effect. It was found, however, that by careful adjustment of the conditions of cooling, it was possible to eliminate the porosity entirely and to reduce the segregation due to micro-banding to negligible proportions.

Introduction

Among the many alloys produced by the centrifugal method at the David Brown Foundries Company of Penistone for use in gears, bearings, sliprings, sleeves, piston-rings, etc., one such nickel-bronze alloy has presented unusual difficulties in manufacture. One major problem, the investigation and solution of which is described in this Paper, demonstrates in an acute form a hazard that is of minor consequence in many more-easily-produced materials. As a result, the whole manufacturing procedure requires special supervision and inspection to attain the high quality required in the castings.

The castings in this particular alloy are produced in the form of two sizes of rough-machined blanks for the manufacture of big-end and intermediate crankshaft bearings in a Diesel engine. Dimensioned drawings at various stages in the process are shown in Fig. 1. The nominal composition of the material is as follows:—Nickel, 18; tin, 5; lead, 5 per cent., and copper the remainder. It must be substantially free from zinc, silicon and aluminium, as these metals are believed to impair the adhesion of the Babbitt metal. A minimum Brinell hardness of 100 is specified and this value is realized with ease in sound material.

Typical results of compression tests on the centrifugally-cast material are given in Table I compared with those of the standard phosphor-bronze gear material to specification B.S. 1400, P.B.2C. It will be seen that at low compressive stresses, it is more plastic, but thereafter shows a greater resistance to deformation than the phosphor-bronze.

TABLE I.—*Relative Compressive Stress of Centrifugally-cast Standard Nickel-bronze and Phosphor-bronze.*

Compressive stress, tons per sq. in.	Nickel-bronze, per cent.	Phosphor-bronze, per cent.
10	0.25	0.05
20	0.88	2.80
30	4.50	7.00
40	9.60	14.50
60	27.00	27.00

Due partly to the readiness with which an alloy of this type is likely to absorb gas and also to the large temperature interval over which solidification takes place, problems due to lack of soundness are to be expected. An inverse-rate cooling-curve for the alloy, shown in Fig. 2, illustrates this latter point, whilst the fact that lead is insoluble in the major constituents indicates that solidification will not be complete until the freezing point of this metal is reached. However, quite apart from its value with regard to the bearing qualities, the addition of lead is essential in order to render the alloy an economical machining proposition. This was demonstrated to the personal satisfaction of the Authors when, during the course of the experiments, a material devoid of lead was examined.

Description of the Defect

The defect described in this Paper was first noted on the final machining of the Babbitt metal where, on certain bearings, small circular depressions were observed. A photograph of one such area of pinholing is shown in Fig. 3. In cases where this could not be traced to a fault in the metalling operation, it was found that on fracturing the shell that the surface showed regions of discolouration which were generally pink in colour. Subsequently, it was discovered on extremely careful inspection immediately prior to metalling, that such bearing shells could be recognized by a slight darkening of the internal surface and also that some, but by no means all, could be similarly identified at the stage where they were rough-machined blanks.

Preliminary observations suggested that the

* Presented to the Fiftieth Annual Meeting of the Institute of British Foundrymen.

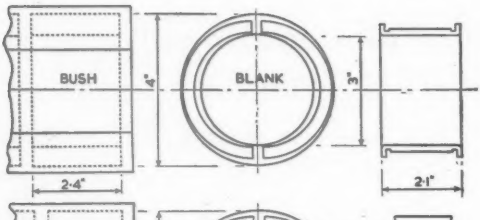

FIG. 1.—*Stages in the Manufacture of the Bearings from Centrifugally-cast Blanks; (upper) Big-end Bearing, and (lower) Intermediate Crankshaft Bearing.*

pinholing in the Babbitt metal might be due either to a segregate giving a discoloured fracture and darkened machined surface or to slight porosity in the base metal. Accordingly, a number of shells exhibiting this defect was radiographed on fine-grain film, using a low X-ray tube voltage in order to give maximum contrast. It transpired that in all cases the shell was porous, but that the unsoundness extended over a much bigger area than that over which pinholing occurred. One of these bearings was then subjected to a prolonged immersion in fluorescent crack-detection fluid, followed by washing the surface in alcohol to remove excess solution. The bearing was then fractured through the pinholed area and the exposed faces were examined under ultra-violet light. The fluorescent medium revealed a region of porosity considerably greater in area than that of the pinholing, and as far as could be judged, it corresponded with the porous region revealed by the radiograph. However, in daylight it was seen that the area of discoloured fracture lay within, but did not cover the whole of the porous areas, and that the outcrop of the discoloured region corresponded with the pinholing. The location of the porosity, pinholing and discoloured areas is represented diagrammatically in Fig. 4.

The importance of the evidence of the fluorescent solution treatment is not so much a confirmation of the radiographical evidence as a demonstration that the pores are inter-connected. It was concluded that the discoloured region was one of comparatively gross porosity and that the outcrop of this region alone was responsible for the pinholing of the Babbitt-metalled surface.

Mechanism of Bubble Formation

Careful examination of the pinholes on the metalled surface illustrated in Fig. 3 and of a micro-section of a bearing cut through a pinhole shown in Fig. 5, indicated that they were, in fact, parts of spherical bubbles formed in the Babbitt metal when still molten. Since they occurred only on the surface of bearings containing porous metal and in some cases (as in Fig. 5) the bubble can be seen directly above an extra-large pore, it seemed probable that they were formed by gas emanating from such pores.

At this point it is necessary to make a brief reference to the metalling process for evidence of the evolution of gases. The procedure consists in preheating and fluxing, followed by running on the Babbitt metal at a considerably higher temperature. After cooling, the excess metal is machined away to leave a thin even coating on the nickel-bronze shell. From this description, it is evident that gas (either entrapped in the pores or from volatilization of flux which seeped into these cavities), on sudden heating occurring during the preheating to the metalling temperature, could produce streams of bubbles some of which might be trapped by the solidifying Babbitt metal.

The ejection of bubbles from the cavities would be opposed both by the pressure head and the surface tension of the metal. The first is a constant, depending on the depth of the orifice below the surface of the metal, while the second is dependent on the radius of curvature of the bubble. It can be shown mathematically that the pressure due to surface tension is inversely proportional to its diameter, and that as a bubble builds up at an orifice, the pressure rises to a maximum when the diameter is equal to that of the orifice after which it falls until the bubble becomes detached. A pressure wall is therefore created and, at a given value, only holes over a certain size are capable of producing bubbles.

In order to confirm this method of bubble for-

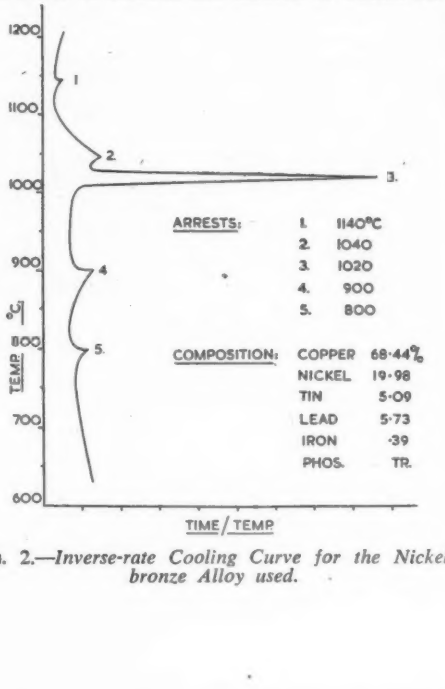

FIG. 2.—*Inverse-rate Cooling Curve for the Nickel-bronze Alloy used.*

mation, it was decided to simulate the metalling process with the exception of the fluxing treatment in such a way that any such effect could be observed directly. For this purpose, finished shells exhibiting pinholes and unmetalled bearings showing a slight darkening of the inside periphery were chosen for the test. After preheating in a laboratory oven, they were completely immersed in glycerine held at the same temperature as that used for the metalling process. Almost immediately large bubbles formed over the discoloured areas while only after a considerable time did minute bubbles appear on the immediately surrounding areas. It was also found that bubbles formed above a proportion of the pinholes in the metalled bearings.

From this experimental evidence it was concluded that only the areas exhibiting a discoloured fracture were likely to cause bubbles in the Babbitt metal and that the gas responsible for the effect was entrapped in the pores of the backing metal so that any due to the volatilization of the flux could only be complementary.

Gas Porosity

It was considered probable that the microporosity associated with the metal exhibiting the discoloured fracture was due to gas evolution from the metal during the freezing process. Observations were therefore made on a large number of production heats with a view to correlating the quality of the bearings with normal variations in foundry practice likely to influence the gas-content of the metal. During this period, a number of heats was subjected to modified treatments while melting, with the intention of reducing the amount of dissolved gas in the molten metal.

At the time at which this work was carried out, the exact relationship between the discoloured fracture, the porosity and the pinholing of the Babbitt metal was still open to doubt, so that the assessment of the quality of the metal was by correlation with the proportion of returned scrap. In this, the co-operation of the user was freely given in maintaining the identity at all stages of manufacture. Although based on the ultimate criterion of saleable or unsaleable bearings, the method had a number of disadvantages. These included the delay which would necessarily occur between the casting and the return of all the defective bearings, and the fact that the absence of pinholing of the Babbitt metal was no guarantee that such defects in the metal did not occur somewhere within the bearing shell. On the other hand, not all pinholes formed in the Babbitt metal have their source in the defects of the packing metal.

The first of three methods of treatment of the melts was the substitution of an oxidizing flux of 3½ lb. of pyrolusite for a 400-lb. heat in place of a proprietary flux normally employed. It was hoped that this would have maintained the bath in a sufficiently oxidized condition to prevent the absorption of hydrogen and possibly also that of carbon monoxide, but the results, recorded in Table II, suggest that it had a slightly detrimental effect. This is a remarkable result in view of the fact that a subsequent analysis of the proprietary flux normally used showed it to consist largely of pyrolusite and powdered glass. The second method tried was the addition of titanium to the metal bath just before pouring, since in certain similar instances this treatment has proved efficacious. The additions were made in the form of a low-aluminium, nickel/titanium master alloy to give final titanium contents varying from 0.2 to 0.02 per cent. The results, also recorded in Table II, showed that there was a certain amount of improvement, but, in view of the wide variations shown in this work, no further action was taken.

The final method used was scavenging with commercial nitrogen from a gas cylinder. Graphite degassing tubes drilled with very small holes for

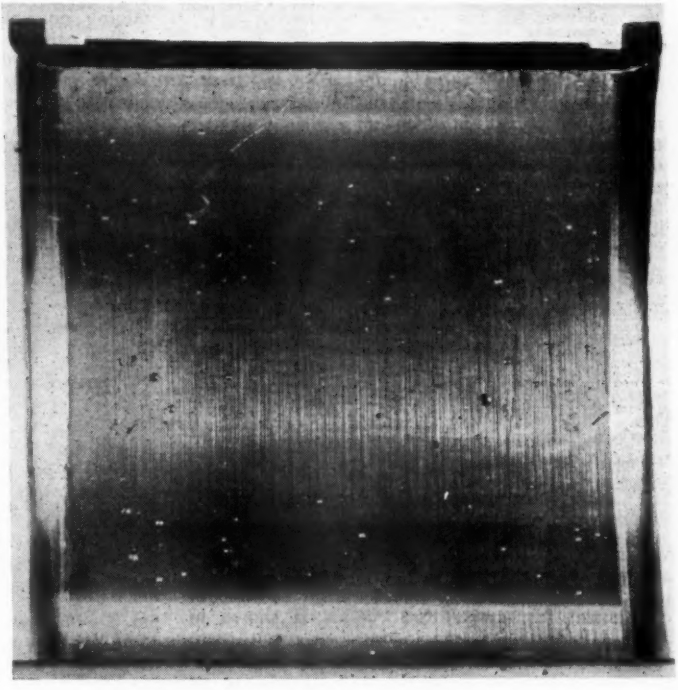

FIG. 3.—*View of the Internal Face of a Big-end Bearing, showing Pinholes.* ×2 *mags.*

FIG. 4.—*Connection between Pinholing and Porosity in the Nickel-bronze Bearing Shell.*

the dispersion of bubbles are normally used for this purpose, but, with the high proportion of nickel in the alloy, it was considered that contamination of the metal might result. The gas was therefore projected over the surface of the metal bath so that dissolved gases might diffuse into the atmosphere. As the results of this experiment, shown in Table II, indicate that this treatment had no effect, it was concluded that this was more likely to be due to an ineffective technique than that scavenging by an inert gas was basically unsound.

TABLE II.—*Scrap Losses on Bearing Shells related to the Method of Treating the Molten Nickel-bronze.*

Treatment.	Small bearing.		Large bearing.	
	No. made.	Per cent. scrap.	No. made.	Per cent. scrap.
Pyrolusite flux ..	170	9	140	7
Titanium addition ..	228	6	178	4
Nitrogen scavenging..	—	—	32	6

During the observations made of normal casting variables in untreated heats, the factors considered most likely to cause large changes in gas-content of the metal were the melting temperature and the occasional addition of cold metal for temperature adjustment. The results of the first of these, divided for convenience into intervals of 10 deg. C., are illustrated in graphical form in Fig. 6. The large variations in the proportion of scrap over the temperature range should be treated with caution, since, from a statistical angle, the "population" is very unevenly distributed, but it suggests that the sudden changes may be associated with some unrecorded factor. The effect of the addition of cold metal for temperature control is shown in Table III, and the same inconsistent results were obtained, which gave further emphasis to the view that some unrecorded variable was responsible. The outstanding conclusion to be drawn from this analysis was that the solution to the problem was more likely to be found in the casting than in the melting practice, since the proportions of scrap varied independently for the two sizes of bearing, although they were cast from the same heats of metal.

TABLE III.—*Influence of Adding Cooling Metal, before Pouring, on the Scrap Losses Encountered by Users.*

Amount of added cooling metal.	Small bearing.		Large bearing.	
	No. made.	Per cent. scrap.	No. made.	Per cent. scrap.
Large	58	7	66	0
Medium	1,052	8	921	1
Little	96	22	74	1
None	763	7	1,282	4
Total	1,969	8.6	2,343	2.8

Towards the end of the investigations, after it had been found that the porosity could be eliminated by a special casting procedure, attention was again focused on the question of gas elimination, since the defect had been traced to the effects of gas dissolved in the molten metal. As it was desirable to prevent solution initially, the possible sources were re-examined. On the assumption that the cold charge did not contain a large amount of gas, the four principal sources of gas pick-up were likely to be (*a*) from the furnace atmosphere, (*b*) from handling, (*c*) the use of oily metal for temperature adjustment, and finally (*d*) the mould-wash, which contained a small proportion of volatile matter.

The possibility of contamination in handling, and temperature adjustment was examined by casting a pair of bushes from a shank containing specially "oiled" metal in the bottom, before very hot metal from the furnace was poured on. Examination by the radiographic procedure (described later) showed them to be free from porosity, so that the gas from this source could only be complementary to that due to other causes. Next, an alternative mould-dressing, having a lower heat-conductivity but containing no volatile material, was tested on two further pairs of bushes. Examination of the bushes cast with very thin coatings of this material showed slight porosity, but when applied thickly the porosity was severe. It was therefore concluded

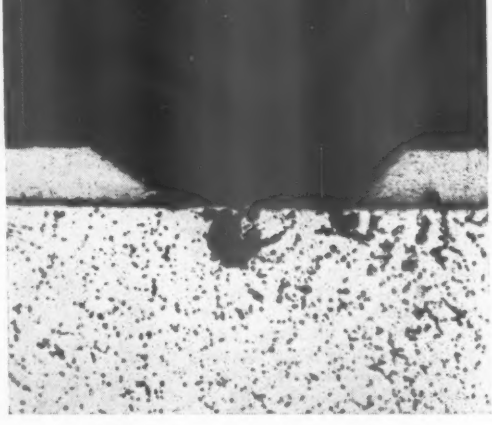

FIG. 5.—*Photomicrograph of a Section through a Pinhole above a Large Pore in a Bearing Shell.* × 50 *mags.*

that the gas must be absorbed prior to its being poured from the furnace. Since all possible precautions had been taken—including preheating the furnace before charging; using dry metal, and the employment of an oxidizing cover flux—it was decided that there was no practical alternative to the special casting procedure as a means of eliminating the inter-dendritic porosity.

Location of the Defective Metal

Experience obtained as the result of fracturing large numbers of rough-machined blanks and finished bearings had shown that the exact location of the defective material was of the greatest importance, as in many cases it took the form of a thin band on the extreme inside periphery of the bearing. It was therefore decided that a study of the factors determining its position might suggest a means of displacing it so that it would be closer to the bore of the cast bush where subsequently it could be removed by machining. Macro-etching having failed to locate the defect with a sufficient degree of precision for the purpose, and since no press of sufficient size was available to break the bushes in the "as-cast" form, clearly a new method of examination was required.

After a considerable number of experiments, a technique involving the radiography of thin slices of metal on fine-grain film was perfected. This is a compromise between the conventional method and micro-radiography, since the former was insufficiently precise to locate the defect, whilst, on the other hand, the difficulty of producing large numbers of specimens of several square inches in area and a few thousandths of an inch thick was immense. Moreover, radiographs tend to reproduce the microstructure to the exclusion of macro-segregation phenomena. For this reason, the thickness chosen is dependent upon the structure it is intended to reveal and must be determined by experiment. Similarly, the X-ray tube voltage must be as low as possible to obtain maximum contrast. There is a limit to this, however, as the consequent increased exposure time involves a greater degree

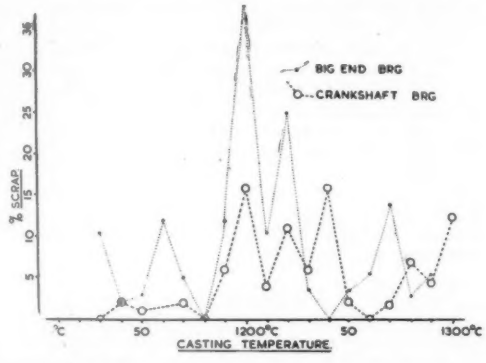

FIG. 6.—*Variation in Scrap Bearing Shells found by Users over the Range of Temperatures employed for their Casting.*

FIG. 7.—*Lead Print of an Unmachined Bush showing a Band of Material apparently Rich in Lead.*

of scatter thus tending to blur the radiograph. In the present work, a specimen-thickness of 0.05 in. and a tube voltage of 100 kv. was chosen. Unfortunately it has not proved possible to include any of these radiographs in this Paper as they do not lend themselves to satisfactory reproduction.

Radiographs of complete transverse and longitudinal sections of a considerable number of unmachined bushes from both the larger- and smaller-diameter bearing were examined. In most cases, it was found that the structure showed slight micro-banding, the pitch-width of which increased progressively towards the axis of the bush. Except at the extreme ends, where they were deflected towards the bore, the longitudinal sections showed that the bands were parallel to the axis; while in the transverse sections, they appeared as incomplete arcs of circles, often joined by irregular step formations. It was concluded that these were a general feature of the freezing process under these conditions and roughly followed the isotherms existing during cooling.

Except at the extreme ends, there was a region of shrinkage porosity to a depth of between $\frac{1}{8}$ in. and $\frac{1}{4}$ in. stretching along the bore. In some bushes, outside this was a further porous layer separated from the shrinkage area by a region of sound material. This latter porosity seldom extended throughout the whole length in an unbroken line or in a complete circle in the transverse section. By fracturing the remainders of the bushes from which the sections were taken, it was found that the shrinkage in the bore which is normally machined away, exhibited a black fracture, whilst the outer band of porosity showed a pink coloration, and was the material responsible for the defective bearings. Normally, this would be located at a diameter slightly smaller than that of the finished bearing. It was therefore not difficult to understand that

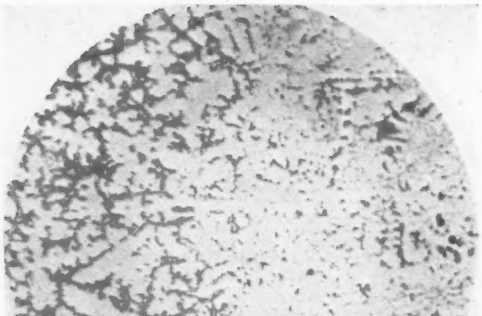

FIG. 8.—*Etched Micrograph of the Junction between the Satisfactory and the Defective Material on the Right, the Latter showing considerably reduced Coring.* ×50 *mags.*

very small changes as a result of normal casting variables would alter the position of the porosity by a distance sufficient to make the difference between a satisfactory and a defective bearing.

Changes in Solidification Process

Sets of four bushes produced for the smaller type of bearing were then cast under controlled conditions and examined by the radiographic method to ascertain any changes in structure and the extent of the porosity.

Casting Temperature.

Bushes cast at 1,250, 1,210, 1,170 and 1,150 deg. C., which cover a normal casting range, showed that neither the slight micro-banding nor the location of the porosity were affected.

Speed of Rotation.

Using the same mould as above and employing a casting temperature of 1,200 deg. C., further sets of bushes were cast at the high, medium and slow speeds obtainable on the casting machines. It was found that as the speed was increased, there was a slight progressive narrowing of the band width. However, whilst the porosity associated with the pink fracture would have machined away in the bushes cast at the two lower speeds, at highest speed there was a tendency for it to break up into a number of very fine layers, some located in the region from which the bearing was machined.

Cooling Rate.

Maintaining the casting temperature and machine-speed constant, by the use of moulds of differing wall-thicknesses, the cooling rate of the metal was varied over a wide range. On examination of the bushes, it was found that the cooling rate was a factor of critical importance. At the lowest cooling rates, banding was completely absent and the pink fracture was dispersed, extending throughout more than half the section, blending into the zone of black fracture in the bore. As the cooling rate was increased, the former type of porosity became progressively concentrated in the form of a band close to the bore, and hence would be removed in the subsequent machining operation. At the highest cooling rates, this porosity disappeared altogether, but considerable micro-banding appeared throughout the whole bush. Clearly, the porosity could be eliminated by this means, but further work was necessary to determine the cause of the banding.

Temperature Gradient.

The importance of the temperature gradient factor has long been recognized in the formation periodically of structures such as have been found in these castings. Moreover, the fact that the high cooling rate necessary to suppress the porosity involved an increase in the intensity of this factor and that the severity of the banding similarly increased, suggested that the two phenomena were related. Changes in temperature gradient were achieved either by supplying or extracting heat from the bores of the castings, or the range was still further increased by partial heat-insulation of the outside of the casting. Pairs of bushes were cast under conditions of varying temperature gradients, and thin sections were again examined by the radiographic method.

In the particular mould chosen for these experiments, when the temperature gradient was artificially raised by supplying heat to the internal periphery of the casting, the consequent reduction of cooling rate in the bore was just sufficient to produce a small amount of porosity, but in the sound material outside this region, considerably more micro-banding was apparent than in those cast by the normal method. By extracting heat from the bore, the temperature gradient was decreased, while still maintaining a high cooling rate, and it was noticed that the micro-banding gradually disappeared. Further lowering the temperature gradient (necessitating the partial insulation of the outside of the bush) proved to be of no commercial value, since the cooling rate was insufficient to prevent the appearance of dispersed inter-dendritic porosity throughout the section.

Clearly, the satisfactory production of bearings is a critical balance of temperature gradient and cooling rate in which such factors as the casting and mould dimensions along with the appropriate dressings, etc., are of special importance. The particular values for these factors have had to be determined by extensive practical trials and differ somewhat for the two sizes of bearing so that the extension of production to rings of different dimensions will require considerable preliminary experiment to determine the optimum conditions.

Lead Segregation

At an early stage during the investigation, the occurrence of some form of chemical segregation was considered as a possible cause of the appearance of the regions giving a discoloured fracture. The colour was thought to be either due to interference films or to the precipitation of a new con-

stituent in the grain-boundary through which fracture occurred. Of the two possibilities, the latter seemed the more likely since the discoloration was almost always the same shade of pink and when occasionally other colours did appear, there was a clear demarcation between them. If this were the case, it would be likely that this constituent would have a high lead content since the latter has a low melting point and is insoluble in the major constituents of the alloy.

Micro-examination of the defective regions showed that the structure was considerably less "cored" and seemed to contain less lead than the satisfactory metal. However, only small areas could be examined at any one time and since there appeared to be a certain amount of variation in the lead content of the satisfactory metal, examination over larger areas was desirable.

Lead printing was carried out on a number of transverse sections of bushes before machining, some of which contained regions of defective metal. Without resort to fracture, these areas were difficult to identify, as the best indication that could be obtained was a slight preferential pitting of the area after acid pickling. However, lead prints, one of which is shown in Fig. 7, indicated little segregation in the satisfactory areas, but there was a considerable concentration of lead in the defective material. This was difficult to reconcile with the evidence obtained by microscope examination, but it tended to support the view that a new constituent was formed, despite the fact that it had not been identified under the microscope. No further work was carried out on this phenomenon until the position of the defective metal had been investigated by radiographical means.

Although, after continued use of the radiographic method for the examination of the bushes, it was obvious that there was normally a certain amount of segregation of either or both tin and lead, the two radiographically dense alloying elements, it appeared very much more pronounced in the porous regions. A fractured defective rough-machined blank, showing a very clear demarcation between the satisfactory and defective areas, was sectioned and radiographed. Subsequently, a lead print was taken of exactly the same area. While the radiograph indicated a low lead content and/or porosity, the lead print showed a concentration of this metal. A micrograph of the defective area, along with an etched section of the junction with the satisfactory material reproduced in Figs. 8 and 9, showed that the defective region was considerably deficient in lead. The defective material showed less "coring" of the structure and, whereas in the satisfactory metal the inter-dendritic cavities were filled with lead, those in the defective region were only partially filled.

A spectrographic spark traverse was carried out across the porous band, but, possibly due to the size of the spark used, no segregation was detectable. However, a portion was carefully sawn out and analysed by chemical methods and gave the results shown in Table IV.

It is obvious that this area was considerably deficient in lead and perhaps to a greater degree than shown by the figures quoted because of the difficulty of obtaining a sample without including some of the surrounding metal. The misleading evidence of the lead prints was probably due to the greater ability of the porous region to hold the etchant and hence its increased ability to affect the printing paper despite the deficiency in lead.

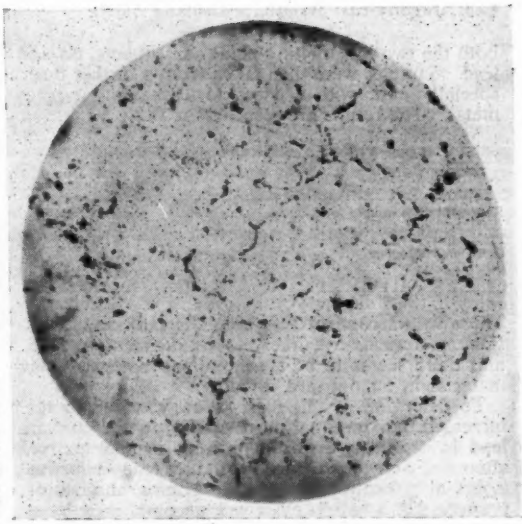

FIG. 9.—*Unetched Photomicrograph of Defective Material, showing Interdendritic Porosity and Depletion in Lead Content.* ×200 *mags.*

TABLE IV.—*Composition of a Representative Sample and the Pink Region taken from Defective Bearing Shells.*

—	Composition, per cent.	
	Representative sample.	Pink region.
Copper	70.16	70.36
Tin	5.12	5.04
Lead	4.91	3.70
Nickel	Difference	Difference

This being the first definite evidence of lead segregation, a complete bush showing both pink and black fracturing porosity was sampled and analysed by chemical means. The results are given in Table V.

TABLE V.—*Composition of Various Regions taken from a Bearing Bush*

—	Composition, per cent.		
	Representative sample.	Pink region.	Black region.
Copper	71.58	71.95	71.81
Tin	4.97	4.95	3.51
Lead	4.53	4.39	2.77
Nickel	18.32	18.02	20.02

In this bush, the demarcation of the pink area was not as definite as in the previous blank examined, but it did show a small depletion in lead. However, in the case of the black area adjoining the inside periphery, it was shown to be deficient in

Centrifugally-cast Ni-bronze Bearing Shells

both the two low-melting-point constituents, tin and lead. Samples were then taken from a further bush, specially cast, with a view to containing porous metal. The results are recorded in Table VI.

TABLE VI.—*Lead Content of the Various Regions.*

—	Lead content, per cent.
Representative sample	3.14
Black region	2.49
Pink region	2.17
Outside pink region	2.87
Outside periphery	4.67

These values confirm that both the pink and black fracture regions are likely to be deficient in lead, and there seems to be a general movement of this material in an outward direction.

To determine if this segregation was due to the increased gravitational field acting on the molten lead in the inter-dendritic cavities in the matrix, attempts were made to reproduce the defective layers in statically cast ingots. After a number of unsuccessful attempts, this was accomplished by a suitable adjustment of the cooling rate in a cast-iron mould. After locating the porous regions by fracturing, samples gave the results shown in Table VII.

TABLE VII.—*Lead Content of Samples taken from a Bush Cast Statically.*

Position.	Lead content.
Sample	5.60
Outside	5.80
Pink region	2.89
Black region	4.36

Since these values show that severe lead-segregation may occur when this alloy is cast statically, the reason for the movement could not be the very high gravitational field, although this may possibly be a contributary factor.

From consideration of the nature of occurrence of the porosity, the fact that it could not be centre-line shrinkage and that it could be eliminated by raising the cooling rate, led to the conclusion that it was due to gas evolution. It is believed that this evolution takes place at the end of the solidification of the copper/nickel/tin matrix, with the result that the lead which is still molten is forced out of the regions in which the gas is evolved.

It remained to determine the reason for the discoloration shown by the fractured surface of the porous regions. Although the shrinkage porosity adjacent to the bore exhibiting a black-fracture surface was shown to contain cuprous oxide by its red colour under polarized light when examined under the microscope, no such coloured substance had been discovered in the pink regions. Attempts were made, therefore, to reproduce possible interference colours by artificial means. A long, thin strip of the metal showing a fractured surface was heated from one end and indefinite "temper" colours were formed, but these bore little resemblance to any found in defective bearings. However, on repeating the test after cleaning the surface with nitric acid, bright colours appeared, including the pink so often found in defective bearings. A feature of the distribution of these colours was that the length occupied by the pink coloration was greater than that of all the others combined. Although not ruling out the possibility of an unidentified compound, it is probable, therefore, that the pink colour is due to interference films.

Conclusions

(1) In cases where the defect could not be attributed to a fault in the metalling operation, the pinholing of the Babbitt-metal facing of the bearing is caused by the evolution of gas from pores in the backing metal during the metalling process.

(2) This porous material differs from the satisfactory metal in so far as the inter-dendritic spaces are only partially filled with lead, whereas normally they are completely filled. It is believed that the lead is forced out by gas evolved towards the end of the solidification of the copper/nickel/tin matrix. It is probable that the pink coloration shown on the fracture of this defective material is due to interference films.

(3) Methods of reducing the amount of dissolved gas in the molten metal, including the rejection of gassy ingots, the addition of small quantities of titanium, and melting under an oxidizing flux have proved unsuccessful in preventing the occurrence of porosity in the castings. Possibly gas contamination during handling and from volatile constituents in the mould dressing can only be complementary to that already dissolved in the metal, so it is presumed that most of the gas is derived from the furnace atmosphere.

(4) Complete suppression of the gas porosity can be achieved at high rates of cooling. However, if this is achieved in a way that involves a similar rise in the consequent temperature gradient as the metal passes through the freezing range, a significant amount of micro-banding is produced. Therefore, the whole question of heat-flow from the casting requires extensive study and in this work, the optimum conditions, which differ somewhat for the two sizes of bearing, have been determined by extensive experimental and production trials.

Glasgow Works Accident

An exploding cylinder killed one man and injured six others in the workshop of L. Sterne & Company, Limited, refrigerator manufacturers, Crown Iron works, North Woodside Road, Glasgow, recently, while Catherine McMillan, crane driver, sat helpless and horror-stricken in her cabin. Killed was David McDonald, 39 year-old inspector, of Milverton Avenue, Bearsden. Detained in the Western Infirmary with face and body injuries was Robert Parker (25), a fitter. McDonald, with three fitters, was testing the condenser—a cylinder measuring 4 ft. by 12 ft. Air was being pumped into it for testing.

Ultrasonic Methods of Inspection*

By M. H. Baddeley

After first outlining the scientific principles involved in ultrasonics, the Author gives a short history of the application of the phenomena to flaw detection. Then, types of instruments and their method of use are dealt with, followed by the effects of frequency and probe design, concluding with a survey of some factors limiting wider adoption of the method for casting examination, despite the introduction of up-to-date modifications, which are also described.

In recent years, inspection methods using ultrasonic waves have attained a high standard of development and the methods used are generally regarded as quite new. The use of ultrasonics in locating objects, however, is by no means new and dates back at least several million years, that is since the evolution of the bat which occurred during the Eocene Age. The "blind" bat uses ultrasonic waves to give him warning of his approach to unseen objects and certain other creatures, notably the porpoise, also uses this method.

The bat, during his flight, utters a series of high-pitched squeaks which reflect from objects in his path and return to his ears, and the time taken for this reflection to occur is a measure of the bat's distance from the object, since the velocity of sound is a constant for any particular medium. The modern ultrasonic flaw-detector works on exactly the same principle. The term "ultrasonic," however, is not a strictly correct one to use in regard to this feature of the bat since "ultrasonic" is a subjective term implying sound waves of frequency above the upper limit of hearing and the bat, of course, hears its own squeaks. However, it is not coincidental that these squeaks are high-pitched. High-frequency sound has special properties which enables it to be used for locating objects. The chief of these being very high directionality.

The waves do not spread out in all directions as do ordinary sound waves, but can be confined within a very small angle and it is thus possible to use them as a means of exploring limited sections of a specimen at a time so that defects can be located accurately. The development of the ultrasonic flaw-detector has taken place over a considerable period of time. As long ago as 1912, Richardson obtained a Patent from the U.S. Patent Office for an apparatus which used ultrasonic waves to detect icebergs in the ocean. This was probably the first application of ultrasonic waves to the location of objects.

Types of Detectors

In 1933, Muhlhauser,[1] in Germany, patented an instrument using continuous ultrasonic waves for locating defects in metal specimens. This early application worked on the transmission or shadow principle shown in Fig. 1 (*a*). An ultrasonic beam is introduced into the material from one side and is picked up at the opposite side. Any defect present blocks off the beam, thus causing a shadow

* Paper presented to the Newcastle branch of the Institute of British Foundrymen.

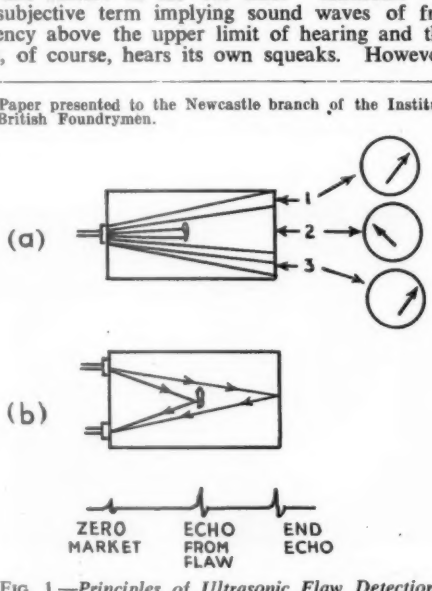

FIG. 1.—*Principles of Ultrasonic Flaw Detection; (a) Muhlhauser's Shadow Method, and (b) Modern Reflection Method.*

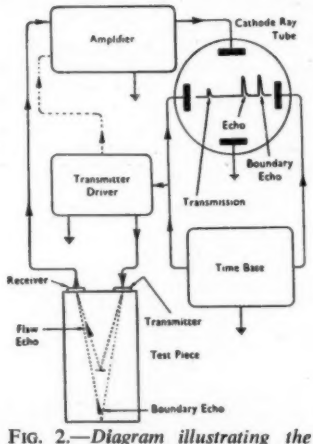

FIG. 2.—*Diagram illustrating the Principle of the First British Ultrasonic Flaw Detector.*

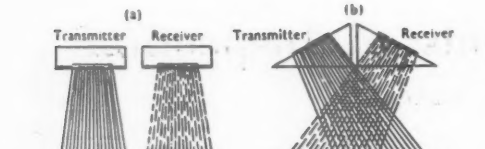

FIG. 3 (*a*).—*Development of Rectilinear Propation of the Beams in a Specimen examined Ultrasonically. Full Lines indicate the Angle of the Transmitted Beam.* FIG. 3 (*b*).—*Wedge Probes for bringing the Sensitive Area nearer to the Surface.*

which may be shown by the receiving device. Modern flaw detectors work on an echo or reflection method which requires a pulsed system, that is, one in which the ultrasonic waves are introduced into the material as a succession of short bursts or pulses (Fig. 1(*b*)). In this way, a pulse is reflected from within the specimen and picked up by the receiver and the time taken for the pulse to traverse the material can be measured by a cathode-ray oscilloscope.

An instrument working on the reflection principle was first introduced by Dr. Firestone[2] in the United States, in 1942 and is the well-known Sperry Reflectoscope. In 1946, Henry Hughes & Company, Limited,[3] (now Kelvin & Hughes, Limited) placed on to the market the first British ultrasonic flaw-detector, the principle of which is shown in Fig. 2.

Principles Involved

The driver unit is a high-frequency oscillator, the output voltage of which is applied across the faces of an X-cut quartz crystal disc. A quartz disc, when polarised, has the property of expanding or contracting in thickness, depending on the polarity of the applied voltage. When an alternating voltage is applied across it, the crystal will expand and contract in sympathy with the alterations thus setting up a vibration. The vibrations thus produced, *i.e.*, compressions and rarefactions, can be introduced into the specimen under test by impressing the crystal upon it. The pulses traverse the specimen and are reflected from the boundary surface opposite, as well as from any discontinuities within the material, and return to the receiver probe, where the reverse process occurs, so that a small alternating voltage is developed across the faces of the receiving crystal.

The reflected pulses, when amplified and applied to the "Y" plate of the cathode-ray tube, cause a vertical deflection of the electron beam in its path across the face of the screen. The apparatus is synchronized so that a pulse of energy is introduced into the specimen under test at the same time as the electron beam commences to sweep the face of the cathode-ray tube. A small portion of this initial pulse is diverted to the amplifier so that a vertical deflection or "blip" is obtained at the commencement of the stroke. The electron beam is deflected from left to right across the face of the tube by means of the time-base voltage which acts upon the "X" plates and thus a fluorescent line is traced out across the tube in a known time.

The reflected pulse, after conversion at the receiver probe, is amplified and applied to the "Y" plate, thus causing another "blip" coinciding with the time it has taken to complete its journey from the transmitting probe. Thus the initial pulse and reflected pulses are delineated on the screen of the cathode-ray tube as a sort of graph, with time as the base. The Firestone instrument, unlike the Hughes, uses only one crystal which works in conjunction with an electronic switching device, it being switched alternately from sending to receiving, so that it receives its own pulses.

Ultrasonic waves introduced in the material behave in a similar manner to light waves, reflections and refractions taking place according to known laws, so that it is possible to base interpretation of results from ultrasonic probes on these. Ultrasonic waves undergo very severe refraction when passing from one medium to another so that a considerable loss is sustained at the interface between the probes and the workpiece, due to the fact that the critical angle is very small and a large amount of energy is reflected back. It is essential

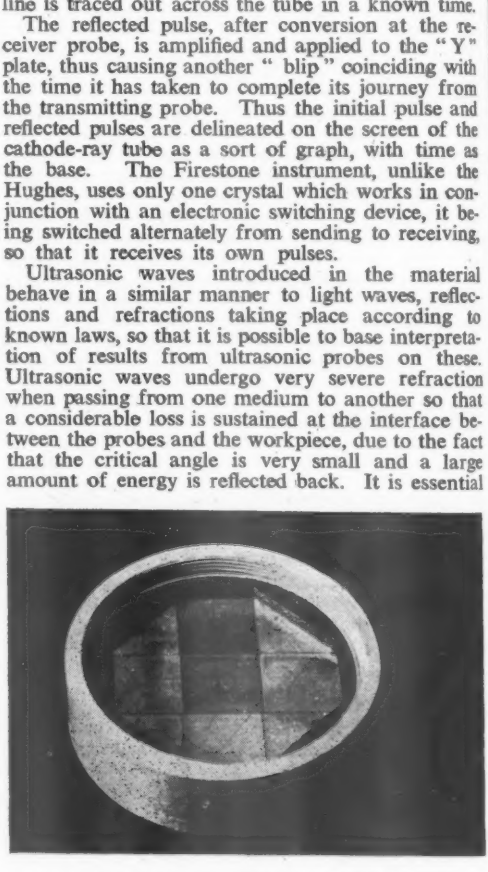

FIG. 4.—*Mosaic Probe made up of Several Crystals. This is suitable for examining Large Castings and is cheaper than a Single Large Crystal.*

to exclude air from this interface since sound waves are not so freely transmitted through air and for this reason a film of oil or some other couplant is used between the probe and the work.

Frequency

The frequency of the vibrations has an effect upon the results obtained, in more than one way. The ultrasonic beam diverges as it leaves the probes, taking the form of a truncated cone, and this angle of divergence depends upon the frequency and the diameter of the probe used. The higher the frequency the smaller is this angle of divergence. Sensitivity of flaw detection increases with increase of frequency. This is because diffraction of the waves takes place around obstacles and, where defects are small compared with wavelength, no reflections are produced. At very high frequencies, *i.e.*, 10 megacycles per sec. and above, sensitivity is so great as to give reflections from such things as crystal boundaries and minor inclusions, so that frequencies in excess of 5 megacycles per sec. are rarely used.

The higher frequencies give rise to the necessity for fine, smooth surfaces for contacting the probes and so for general work, particularly for castings, a lower frequency is used. It is common to work at about 1 MC. per sec. for inspection of castings where minor defects are not of great importance. For cast iron and large steel castings, such as ingots, particularly when not heat-treated, a lower frequency of, say, ½ MC. per sec. is advisable.

Probes

The diameter of the probe governs, together with frequency, the angle of divergence of the ultrasonic beam which becomes smaller as the size of the probe is increased. It is useful to know this angle when interpreting oscillograms and certain deductions from the theory give a simple expression relating the angle of divergence with the frequency and

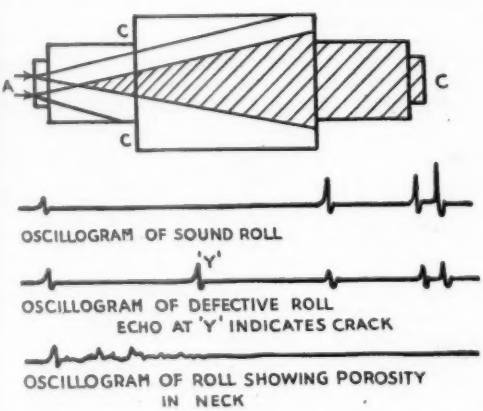

FIG. 5.—*Ultrasonic Test on a Cast Roll—Preliminary Longitudinal Exploration. The Shaded Area shows the Area covered at Any One Probe.*

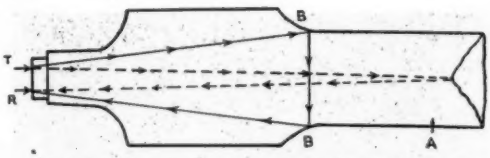

FIG. 6.—*Example of Interference during Examination of a Roll Casting, caused by "Shear" Wave Vibrations recorded on the Oscillogram from Points B. These might be confused with Actual Defects at A.*

probe diameter, *i.e.* $\text{Sin } \theta = 1.2 \frac{\lambda}{D}$

where θ is the half angle of divergence; λ is the wave-length and D the diameter of the probe.

The usual relationship between wave-length, frequency and velocity holds for ultrasonic waves. Fig. 3(*a*) shows diagrammatically the way in which rectilinear propagation of the beam occurs in a specimen, the full lines indicating the angle of the transmitted beam. The broken lines emanating from the receiver probe show that a similar directional characteristic is also obtained, but in this case there is, of course, no beam being emitted. However, the receiver is sensitive only over a similar limited area and only where the two cones of directionality are common will strong reflections be obtained. Where dual-probe systems are concerned, therefore, the angle of divergence should be known.

It can be seen from Fig 3(*a*) that defects very near the surface will not cause reflections, since they do not intercept this common region and wedge probes (Fig. 3(*b*)) are therefore available for bringing this sensitive area nearer to the surface.

Other types of probe available are those having curved surfaces, concave or convex, for use on rounded specimens and very small probes are available for working on restricted faces. Small probes, however, are not very "directional" and are therefore not often used, probes of 2 cm. dia. being about the smallest in general use.

A very useful type of probe for large castings such as rolls and ingots is the large mosaic. This consists of several crystals arranged in a pattern (Fig. 4) and has the advantage of a larger power output, since all crystals are matched so that they vibrate in unison. A single large crystal would also give a greater output, but the cost of such a crystal would be very high.

Applications

Before discussing the various applications to which ultrasonic testing can be put, it is advisable first to describe one in particular. Cast-steel rolls lend themselves admirably to this type of inspection and certain limitations and problems of the method are better explained by reference to this application. A longitudinal test is first conducted from one end, as shown in Fig. 5. It is possible to cover practically the whole of the roll in this manner by placing the probes at various points on the

FIG. 7.—*An Example of Spurious Reflections from a Long, Thin Sleeve explored Longitudinally. The Major Reflections are the First, followed by Two Repetitions.*

end faces. The shaded portion shows the area covered at one time.

Reflections will be obtained from the faces at the remote end, *i.e.* the end of the barrel and the bottom end of the roll and from any defects occurring in the shaded portion. Any defects thus found may be marked off on a drawing and if necessary further exploration can be conducted transversely from the positions indicated. The diagram shows the types of oscillogram which would be obtained from sound and defective rolls. A crack or any well-defined discontinuity lying transverse to the beam, will give rise to a clearly-defined reflection and can thus be recognized. Porosity due to shrinkage or gas inclusion will cause haphazard reflection and refraction resulting in a bunch of numerous "blips" on the screen. Severe porosity cuts off altogether any energy from traversing the specimen completely and no end echoes will be obtained.

The extent of a "pipe" defect can be traced along a neck by transverse examination and any internal transverse crack (a defect sometimes met with in large rolls) will, on transverse examination, *i.e.* where the beam travels with the crack, cause a sudden loss of bottom echo, due to the fact that the ultrasonic energy is easily dissipated along the fissure. Thus the techniques used are quite straightforward and there is practically no limit as to the size of roll which can be tested in this way, indeed, larger rolls are often more easily examined than smaller ones. Rolls up to 20 ft. in length have been satisfactorily tested at the Author's works.

Spurious Reflections

There are, however, some difficulties which are likely to cause trouble, particularly where spurious echoes are obtained. These spurious echoes may interfere with interpretation and are due to several different phenomena, that of wave transformation being the most interesting and important.

The beam of sound introduced into the material is due to longitudinal vibration, that is, when the particles of the material are vibrating in the same direction as the beam is travelling. When the beam strikes a surface at an angle other than 90 deg. a transformation may occur and part of the energy is then reflected as a transverse or "shear" wave. This transverse wave has a velocity of about half that of the longitudinal wave and the particles of the material are there vibrating at right angles to the direction of the beam. This change in velocity can cause misinterpretation of reflections since the time base is generally reckoned on the basis of the speed of the longitudinal wave. An example of how interference may occur is shown in Fig. 6. An echo due to transformation at the radius (B) might be received giving rise to the suspicion of a defect further up in the neck at (A). Where specimens of a more-complicated shape are concerned, this type of reflection can seriously impair intelligent interpretation of the oscillogram.

This type of spurious reflection is obtained where part of the beam bounces off the sides of the specimen and takes a zig-zag course. This is more noticeable on long, narrow specimens, when a number of reflections can be obtained. Spurious reflections, however caused, always appear after the primary echo and the first echo received can therefore be accorded a direct interpretation and can be used as a base upon which to consider the rest of the oscillogram. Testing from various points often enables one to distinguish between direct and spurious reflection.

Another example of spurious reflections is shown in Fig. 7, which is an oscillogram obtained on a long, thin sleeve explored longitudinally. Two distinct groups of echoes are noted, each group consisting of the direct echo with two smaller indirect echoes which are due to part of the beam zig-zagging and transforming. The major reflections are the first, followed by two repetitions, *i.e.*, the beam has traversed the specimen twice, being reflected at both ends. It can be seen that the interval between the zero marker and the first reflection is not the same as that between the first and second reflections, which at first seems surprising, since these intervals represent one and the same length. The reason for this is that it is not possible to obtain a perfectly linear time base on the oscilloscope, so that it is sometimes necessary to allow for this discrepancy.

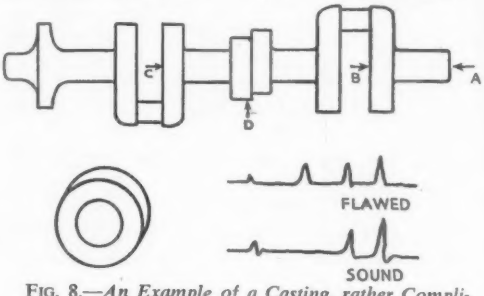

FIG. 8.—*An Example of a Casting, rather Complicated for Ultrasonic Testing, where a Reflection would show up even in a Sound Casting.*

(*Continued on page* 274)

"Foundry" Development in the Textile Industry*

By B. Gale

(*Continued from page* 229)

Developments

Figs. 15, 16 and 17 show the development over the years of the manufacture of special carding engine flat castings. Fig. 15 shows the type of old floor/plate pattern used, whilst Fig. 16 shows the old floor/plate method arranged for production on a rail-line system with the use of a portable crane, the vertical web of the pattern stripping through the pattern plate. Fig. 17 shows the latest development of a mechanized plant for producing these items in which the patterns are mounted on to two pairs of pin-lift pneumatic machines, and the moulding is effected by two impellor-type ramming machines, fed from large hoppers, which are in turn supplied from the main sand-supply system. The large hoppers are fitted with creeping belt feed to the hopper on the machine, and these belts are wired in sequence with the sand-slinging machine, so that sand flows or stops at the will of the operator on the machine head. Pouring is done on gravity-type roller track from monorail ladles and then the moulds travel to a vibratory knock-out grid.

Considerable improvements have been made in the manufacture of the larger frame castings. Fig. 18 shows a hand pattern of the old type for a carding engine frame to be made by skilled loose-pattern moulders, and Fig. 19 shows the same type of job mounted on a floor-plate for moulding under cranes, and rammed by pneumatic rammers. Note the sturdy construction of this patternplate. Fig. 20 shows the same sort of job mounted as part of a mechanized plant, with a line of moulding machines, fed by impellor-type sand-ramming machines, with a complete sand supply system. The size of the moulding box is 13 by 2 by ½ ft.

Other Castings

Figs. 21, 22 and 23 show a similar development on the gearing-end castings for ring spinning frames, Fig. 21 illustrating a loose pattern, and Fig. 22 the plate/floor moulding method; it is interesting to note here the method of handling employed in the foundries making this class of work. Each floor has a long, hydraulically-operated beam crane with its trolley moved by hand. This type of crane is in use in several of the Group foundries, each foundry containing numerous beams so that each squad of moulders has its own crane and works its line of moulds under the long beam. The crane, with its movable trolley, therefore handles all lifting, rolling-over and pattern-drawing operations, and also carries the ladle of metal for pouring. The Author has never seen in vogue a better method of handling large plate work. In the more modern foundries equipped with several electric travelling overhead cranes, it is common to see certain teams

* Presented at the Fiftieth Annual Meeting of the Institute of British Foundrymen. The Author is foundry manager of the Howard & Bullough, Limited, foundries of Textile Machinery Makers, Limited.

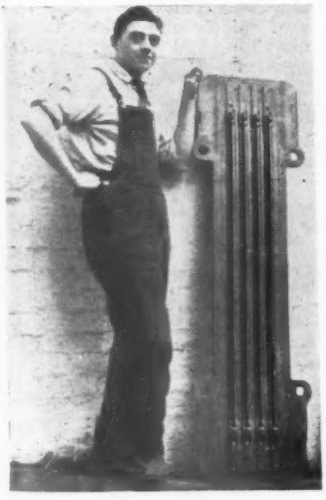

FIG. 15.—*Plate Pattern used for Carding-machine "Flats."*

FIG. 16.—*Rail-line System previously adopted for producing Carding-machine "Flats."*

FIG. 17.—*One Station in the Mechanized Plant for producing "Card Flats" by using Impellor-type Sand-ramming Machines with Stripping Machines.*

waiting for a crane, but in the shops described such waiting never occurs, and this layout has been in operation well over 50 years, a tribute to the productivity-mindedness of the old Lancashire foundrymen.

Fig. 23 shows a mechanized impellor-type sand-ramming plant using patterns mounted on hydro-rollover moulding machines. The moulding box sizes are 70 by 50 by 7 by 4 in. An interesting practical feature of this method is that the Author has found that, to prevent scabbing and similar faults on castings of such large plate area, it is necessary to provide a cushion of loose sand over the pattern face, before ramming by sand slinging. A shutter door has therefore been devised in the ramming-machine feed channel, in front of the impellor

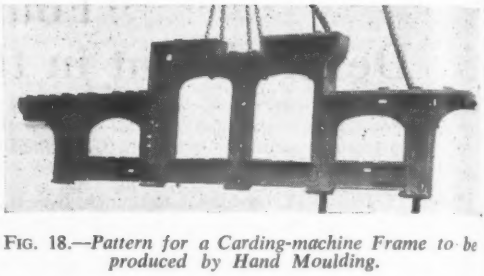

FIG. 18.—*Pattern for a Carding-machine Frame to be produced by Hand Moulding.*

head, which enables loose sand to be ploughed off into the moulding box to cover the pattern. Adjustment of the shutter then permits the sand to travel through to the impellor head for ramming the mould.

Production results by the three methods outlined (hand, plate and impellor-ram moulding) can be stated to be in the ratios of 1:3:5, allowing for the complete operations of sand preparation, moulding, coring, pouring, knock-out and casting removal. Similar developments have taken place on the intermediate sizes of castings and Fig. 24 depicts a completely mechanized system for the production of this group of castings. The plant along with a pallet conveyor is equipped with two large rollover jolt-squeeze machines for the drag moulds and two pin-lift jolt-squeeze machine for cope halves. The moulds catered for go up to 48 by 36 by 4 by 4 in. and the plant is fitted with travelling air-hoists for closing copes on to drags and then to place the complete moulds on to the pallet conveyor. These castings were previously made by hand pattern methods and subsequently on plate pattern or hand-ram roll-over machines on the floor. The production ratios have in these cases increased in the order of 3:8:15.

Spindles and Rollers

The manufacture of spindle and roller castings forms a large and very important part of the foun-

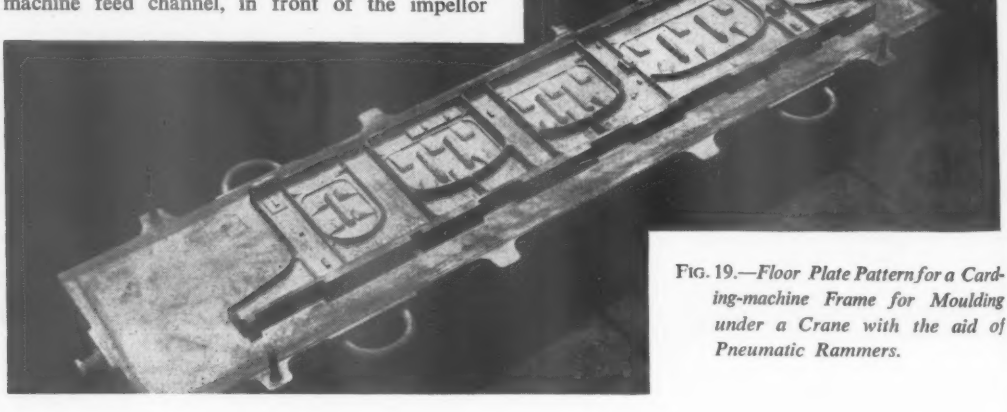

FIG. 19.—*Floor Plate Pattern for a Carding-machine Frame for Moulding under a Crane with the aid of Pneumatic Rammers.*

dry technique required for spinning machinery. These castings are machined at very high speeds and demand perfection in the finished product. Porosity of any type, or even slight openness of metal grain is cause for rejection. The majority of these castings are therefore cast vertically using appropriate running and feeding techniques and, according to design, are made in two- or three-part moulds. The old method was to make these by hand-rammed plate-moulding methods on stripper machines developed by the company.

Fig. 25 shows one of these machines set up with its patterns. Since the war, these castings have been made on a fully-mechanized plant, with specially-designed stripping plate patterns set on jolt-squeeze machines. Fig. 26, shows a section of this plant with the patterns mounted for production. It will be noted that this method of moulding allows for the maximum number of castings in a box, and thus permits high productivity in terms of number of castings produced. Metal to sand ratio per box is high, a fact which in early days gave trouble due to the return of hot sand, but alterations and improvements in the sand-return and feed system have now largely overcome these troubles. However, the constant demands for better quality and higher productivity has led to constant investigations into this sand-supply system and further improvements are now under way for the replacement of the existing continuous sand system by a batch milling scheme to handle this job. The question of sand control is, to the Author's mind, the most important feature of any mechanized plant and warrants the fullest attention.

Sand Control

Every plant within the organization has a completely-equipped sand-testing laboratory, situated on the plant, in charge of a sand technologist, and full readings of moisture, green-bond and permeability are taken and recorded every half-hour, with a further test of the shatter-index at frequent intervals. The main laboratories are also constantly working out new sand developments and control methods. Sand control, therefore, is a very important part of the foundry staff's duties, as the quality of finish on the machines produced is constantly being reviewed and brought into prominence. The skin of castings which are not subjected to machining operations, is of equal importance to the finish of machined parts, so that the painted finish on the castings gives a pleasing appearance to the final product. It is realized and indeed emphasized, that despite all modern cleaning, fettling and painting methods employed, the resultant quality of finish at competitive costs is the responsibility of the foundry and the onus is theirs to produce castings with a very fine skin.

In keeping with the foundries, the dressing-shops have kept pace with the modern developments and each is equipped with the latest types of shot-blast chambers, airless shot-blast machines, etc., but in addition to this it is still practice to barrel a large proportion of the castings after cleaning and dressing, to impart a smooth polished surface to take paint finishes by either dip/stoved or spray/stoved methods.

Machine-shop methods equally are being constantly improved and machining speeds of a very high order are common practice, hence the necessity to equip the dressing shops with large, continuous annealing ovens for the majority of small castings such as spindle parts, rollers, stands, slides, etc. The annealing ovens depicted in Fig. 27, permit an automatic tray movement every six mins. and anneal the castings continuously on shift systems through 24 hours per day. Each oven on this method can handle approximately 100 tons of small castings per week. The time cycle from entrance to exit is 7½ hours.

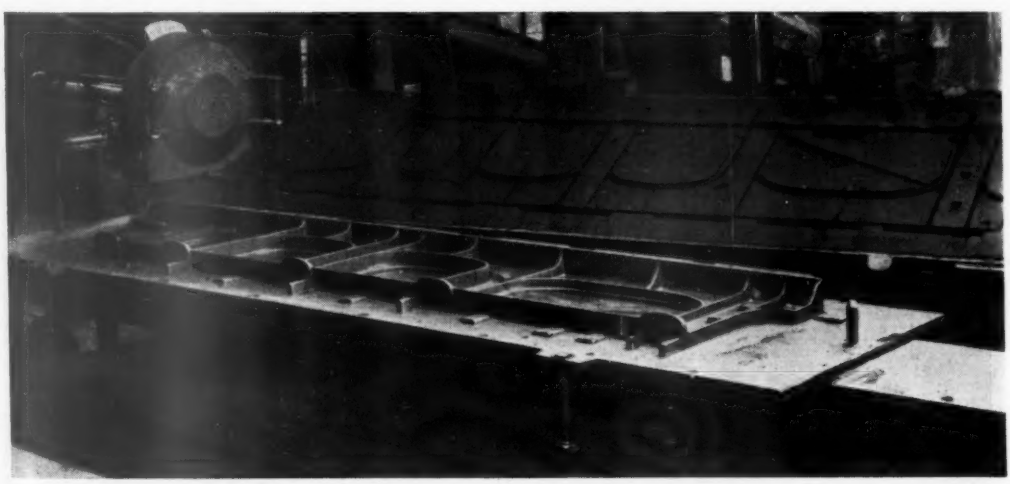

FIG. 20.—*Production of Carding-machine Frames on a Mechanized Plant equipped with Impellor-type Ramming Machines and Crane-operated Turnover Devices.*

FIG. 21.—*Pattern for making a Gearing-end Casting by Hand-moulding Methods.*

Melting and Metal Control

Metal control for all castings on textile machinery plays a very large and important part of the foundry's activities. The castings produced, whilst generally in the class known as light castings, do present many exacting demands for quality. The larger framing castings are of light section with numerous cored slots, holes, etc., to carry parts of gearing etc., and are made in a general, high-phosphoric iron.

The composition is generally of the following order:—Total carbon, 3.2 to 3.3; silicon, 2.4 to 2.6; manganese, 0.7 to 0.8, and phosphorus, 0.8 per cent., which generally shows a carbon-equivalent value of about 4.4. Physical tests on this class of metal will show on the 0.875 in. bar a deflection of 0.19 in. and a breaking load of 1,138 lb. on the transverse test. The tensile strength is about 15½ tons per sq. in. and the Brinell hardness number (with 3,000 kg. loading) is 206. The above figures are the average of seven tests taken at hourly intervals during a typical melt. The C.E. figure aimed for is on the high side for this class of casting as an insurance against cracking during cooling.

The use of the same metal for many of the smaller castings such as levers, brackets, etc., which have severe changes of section, particularly where bosses to carry shafts are connected to relatively thin plates, does cause some concern, and a C.E. value of 4.2 would be more desirable, but the major requirements of the larger castings take precedence and difficulties of porous spots in bosses, etc., are overcome by the foundry technique of running, feeding, chilling, etc.

Special Compositions

Rails and beams for carrying the rows of spindles on spinning machinery demand a close-grained metal and are machined to a very highly polished finish. This is of utmost importance, as a rough, open-grain finish would collect "fly" from the cotton during the spinning operations and would soon clog up the machines. These castings are made in a mixture, a typical composition of which is:—Total carbon, 3.2; silicon, 2.2; manganese, 0.7; phosphorus, 0.8 per cent., and C.E. value, 4.2.

Heavy-section blanks for the production of multi-grooved V-belt pulleys demand a special mixture of high-duty iron, a typical composition being:—Total carbon, 3.12; silicon, 1.70; manganese, 0.73; phosphorus, 0.23 per cent., and C.E. value, 3.76.

Spindle parts which, as previously mentioned, are subjected to annealing, show the following results (taken from the average of hourly tests in a day's melt):—Total carbon, 3.26; silicon, 2.47; manganese, 0.82; phosphorus, 0.24 per cent., and C.E. value, 4.16. A transverse test on a 0.875-dia. bar gives: deflection, 0.28 in.; breaking load, 1,544 lb.; tensile, 15.8 tons per sq. in., and Brinell (3,000 kg.), 197.

The above figures are taken in the "as-cast" condition. Tests carried out on the same samples after annealing give the following results:—In transverse: deflection, 0.29 in.; breaking load, 1,164

FIG. 22.—*Floor/Plate Method of Producing the Gearing-end Casting.*

lb.; tensile, 10.3 tons per sq. in.; Brinell (1,000 kg.), 113.

Melting Practice

Melting is carried out principally in orthodox cupolas, varying from the old solid-bottom type with a receiver forehearth, which used to be the standard method, to the modern drop-bottom types with the pariblast tuyere arrangement and also the ordinary tuyere arrangement. Melting in most cases is continuous through 8 hrs. per day and great care is taken in the preparation of cupolas, particularly in the setting of the tapping bricks. At one plant, so great an emphasis is placed on this feature that a wooden model of the cupola hearth is prepared so that operators can practice setting the bricks for tap-holes and the cupola bottom before they are allowed to carry out this task on production. Modern tendencies are towards the use of the front slagging, continuous running cupola, and this is illustrated in Fig. 28.

Cupola charging receives the specific supervision it requires and all charges and constituent parts of charges are accurately weighed on "easy to read" large-dial weighing machines, which also record all weighings on a printed tape in the machine. The resident foundry metallurgist is in charge of the key to the recording tape and daily checks the weighings to ensure that the job is being done properly. The charging-floor operatives fully understand that negligence in this matter will lead to severe disciplinary action.

Furnace loading is operated in various ways. In several foundries, geographical siting (the foundries being built on the sides of steep hills) has been very advantageously made use of, and the cupolas are so arranged that the charging doors are on street level, so that materials can be conveniently weighed and charged with the minimum of handling.

In other cases, the cupolas stand on ground level and charging is effected by the skip-hoist method. In a third case, however, the exact opposite obtains to the situation first mentioned and here mechanical charging has received the fullest consideration to overcome the difficulties. In this particular case, the stockyard is at ground level, the foundry with the cupola is at the first-floor and the charging door at the second-floor level.

Unusual Cupola Layout

The mechanical charging scheme set-up for the situation mentioned last is the most complete the Author has known. Fig. 29 is a line drawing of the layout. At ground-floor level, an electric weigh-truck runs the full length of the floor on a sunken track. On either side of this track, bunkers are arranged to store various types of materials, pig-irons, scrap, coke, limestone, etc. Drop-bottom charging buckets, when placed on the electric weigh-truck, are so arranged that the top of the bucket is level with the floor of the bunkers so that materials from the bunker are easily scraped into the bucket, and automatically weighed. The truck travels along to each bunker in turn until the full charge is in the bucket and the weights recorded. It then

FIG. 23.—*Set-up for producing the Gearing-end Casting on a Mechanized Plant by using an Impellor-type Rammer for Moulding.*

FIG. 24.—*Mechanized Plant for the Production of Intermediate Sizes of Textile Machinery Castings. The Plant incorporates a Pallet Conveyor and Two Large Rollover Jolt-squeeze Machines for the Drags and Pin-lift Jolt-squeeze Machines for the Copes.*

FIG. 25.—*Old Stripper-type Machine developed for Producing Spindle Parts.*

travels to a point under the hook of the crane-type cupola charger.

This is a travelling electric crab with synchronized switchgear and operates on the pressing of one button. The bucket is thus elevated to the charge-hole level, stops automatically, the electric crab moves forward into cupola and stops, the bucket lowers until it engages on a "wishbone" inside the cupola shaft which operates the cone bottom and discharges the material. It then hoists to close the cone bottom and lift the bucket clear of the furnace sill. Thereupon, the carriage withdraws from cupola and stops, the bucket is brought down to stop at a point about 6 ft. above the track. This latter halting point is to prevent the bucket lowering right down to the track, while the truck has gone down the track for filling a second bucket. As stated, the entire operation is sequence controlled from one press of a button and is fully automatic, no labour being required at charging level.

Another interesting feature of this plant is that an electric "eye" is arranged to shine through the cupola shell at charge-height level, which alternately lights a red or white lamp visible to the loading operatives some 50 ft. below. When metal is charged to full height, the red lamp shows to warn loaders not to send any more metal up. When the melting has allowed the charges to sink in the stack, the white light shows and charging can proceed.

UTILIZATION OF BORINGS

The group foundry managers' and metallurgists' committee which meets monthly to discuss problems and methods, has spent considerable time over the past year or so on the question of reclamation of borings, to provide an added source of raw materials to the foundries. Two years ago they decided against any method employing cannisters or briquettes in favour of direct-arc electric melting. As a result, a Birlec three-phase arc furnace was installed for the specific task of melting 100 per cent. borings, which, with slight corrective additions of ferro-silicon would be poured direct into textile castings. The Author was in charge of the foundry selected for this development and is therefore able to give some of the test results.* Fig. 30 shows the installation, which comprises a Birlec type "S" Lectromelt furnace of 500 k.v.a. 3-phase direct arc, with a nominal rating of 10 cwt. per hr. Its present capacity is 15 cwt. and it is acid lined. Four low-tension voltages are available: 194, 167, 112 and 85 volts, and the furnace current can be regulated in 8 steps up to a maximum steady load of approximately 1,500 amps. The plant (at the time of writing) has been in operation for approximately four weeks on day-shift only, and is now successfully producing two types of cast iron, a general iron and a low-carbon, low-phosphorus iron which are being poured directly to make castings. After obtaining a molten bath at the beginning of each run, 100 per cent. cast-iron swarf is melted subsequently with but small corrective additions of carbon, ferro-silicon or steel scrap.

Operational Cycle

At the start of a run, 2 cwt. of clean foundry returns or scrap castings are charged into the cold

* Work on this method is, of course, still proceeding, but delivery of the furnace only took place some two months before this Paper was completed for publication, and therefore full details could not be available, but additional was given during the actual presentation of the paper at the Conference.

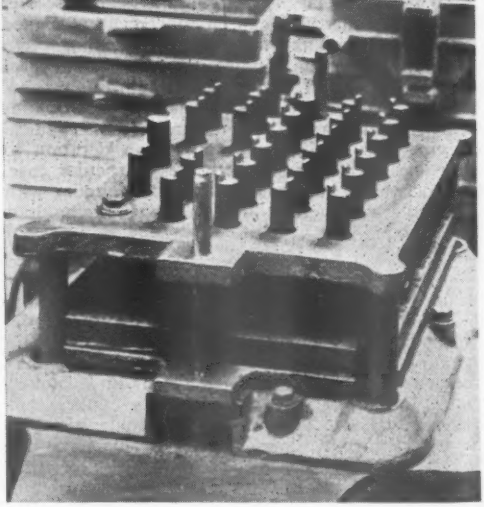

FIG. 26.—*Spindle Patterns arranged on a Stripping-plate Moulding Machine and forming Part of a Mechanized Plant.*

furnace and melted under full power. After approximately ½ hr. this material is molten and the furnace lining is well heated. The power is switched off and about 4 cwt. (1 ladle) of cupola metal is added. Power is switched on again, and the metal further heated to restore the temperature. One lb. of granular charcoal is put on surface of the bath to provide a non-oxidizing atmosphere, and sufficient ferro-silicon "fines" are added to bring the silicon content up to the desired amount, and then with the power kept on at full voltage and current, swarf is shovelled in, being thrown into the arcs as much as possible. The swarf is charged in lots of 1½ cwt. at approximately 4-min. intervals and with each lot is mixed 1 lb. of charcoal blacking to minimize carbon loss. This is continued until the furnace is full—approximately 14 to 15 cwt. As soon as the last addition of borings is nearly melted, the voltage is reduced from tap 1 to tap 2 to minimize heat radiation to the walls and roof from the arcs which are no longer shielded by swarf. When the charge is completely melted, the electrodes are raised and the bath is rabbled. If any slag is present, it is pulled off and then the metal is raised to the required pouring temperature on a further reduced voltage (tap 3); as soon as it is hot enough a quantity of 10 to 12 cwt. is poured and cast. Charcoal is then added to the remaining metal bath of approximately 3 cwt.; ferro-silicon is added as before; power is put "full-on" and charging of borings is immediately recommenced for the next heat.

The above cycle is the normal one at the start of the day and is continued when melting general iron swarf. When making low-phosphorus iron, 50 per cent. low-phosphorus iron swarf is added in the preceding heat of "G" iron to lower the phosphorus content of the bath which remains to start the heat of low-phosphorus iron, and then all low-phosphorus swarf is charged with the usual carbon addition. One cwt. of scrap bar steel is also added to lower the silicon content—by approximately 0.15 per cent.—and this also has a diluting action on the carbon and phosphorus, lowering the former by approximately 0.20 per cent. and the latter by 0.02 per cent.

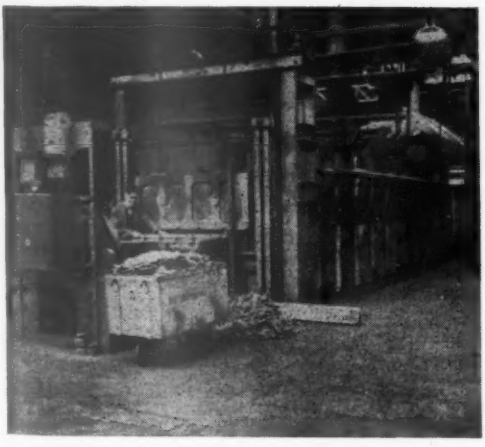

FIG. 27.—*Continuous, Gas-fired Annealing Furnace arranged for Delivery of Trays every Six Minutes.*

FIG. 28.—*Front Slagging and Tapping Box on a Cupola, delivering Metal into a Barrel-type Receiver.*

This cycle of charging operations has been adopted after trying various methods and has been found (an the basis of experience to date) to give maximum production with minimum power consumption and minimum carbon loss. It has been found best to run without any slag covering on the bath as this seriously interferes with charging swarf into an existing molten bath, and is not always easy to remove. In any case, it has been proved that a molten bath can be held at high temperature, completely uncovered, for over an hour with only small silicon and manganese loss and no loss of carbon.

Metallurgical Considerations

Carbon content.—Maintaining a satisfactory carbon content in the metal produced by melting borings has proved to be the most difficult "teething trouble." The swarf arrives at the furnace and can be charged into it with negligible carbon losses (*i.e.*, very slight mechanical loss of loose graphite) and once the metal is molten, the carbon loss is nil, but between charging and melting, considerable carbon loss can occur due to the burning-out of surface carbon. This occurs as soon as exposed swarf surface is hot enough to react with the oxygen of the atmosphere. With general iron swarf, carbon loss due to burning out has been between 0.15 and 0.45 per cent., the lower figure being obtained with heavy swarf of 3.10 to 3.20 per cent. total carbon in which there is a minimum of free graphite, and the higher loss figure is obtained with much lighter swarf of 3.30 to 3.50 per cent. total carbon, some of which has been annealed

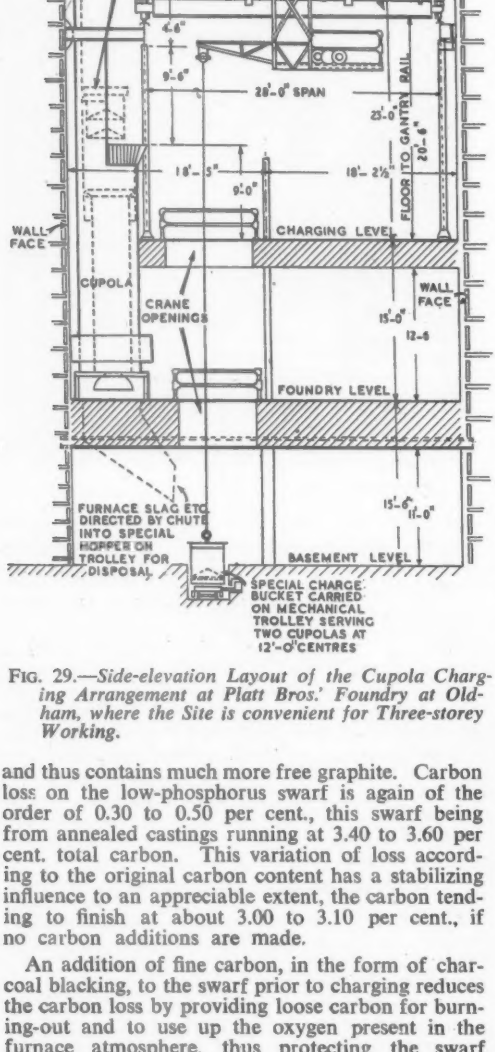
BUCKET RAISED FROM BASEMENT TO THIS LEVEL
OVERHEAD CRANE GANTRY SERVING TWO CUPOLAS AT 12'-0" CENTRES
28'-0" SPAN
FLOOR TO GANTRY RAIL
CHARGING LEVEL
WALL FACE
CUPOLA
CRANE OPENINGS
WALL FACE
FOUNDRY LEVEL
FURNACE SLAG ETC DIRECTED BY CHUTE INTO SPECIAL HOPPER ON TROLLEY FOR DISPOSAL
BASEMENT LEVEL
SPECIAL CHARGE BUCKET CARRIED ON MECHANICAL TROLLEY SERVING TWO CUPOLAS AT 12'-0" CENTRES

FIG. 29.—*Side-elevation Layout of the Cupola Charging Arrangement at Platt Bros.' Foundry at Oldham, where the Site is convenient for Three-storey Working.*

and thus contains much more free graphite. Carbon loss on the low-phosphorus swarf is again of the order of 0.30 to 0.50 per cent., this swarf being from annealed castings running at 3.40 to 3.60 per cent. total carbon. This variation of loss according to the original carbon content has a stabilizing influence to an appreciable extent, the carbon tending to finish at about 3.00 to 3.10 per cent., if no carbon additions are made.

An addition of fine carbon, in the form of charcoal blacking, to the swarf prior to charging reduces the carbon loss by providing loose carbon for burning-out and to use up the oxygen present in the furnace atmosphere, thus protecting the swarf during the critical time between charging and melting. The addition of 1 lb. of blacking to each 1½ cwt. of borings, saves approximately 0.15 per cent. carbon, bringing the final carbon figure to approximately 3.20 per cent. Attempts to recarburize a molten bath containing 2.95 per cent. carbon by immersing the electrodes have resulted in no appreciable carbon pick-up.

Silicon.—The normal melting cycle gives no loss of silicon. In some cases, there has been a definite silicon increase of up to about 0.10 per cent., thought to be due to the reduction of fine sand present in some of the swarf. Additions of ferro-silicon (75 per cent. silicon) in both lump form and as "fines," have been used, and 100 per cent. pick-up is obtained from both. "Fines" arising from the ferro-silicon used in the cupolas are normally used, the usual addition being 1½ lb. ferro-silicon to 10½ cwt. of swarf for general iron to finish with 2.5 to 2.6 per cent. silicon. Holding of a hot, uncovered bath for 1¼ hrs. results in 0.10 to 0.20 per cent. loss of silicon.

Manganese.—No loss of manganese has been detected during normal melting, and it has not been necessary to make any manganese addition. Holding of an uncovered hot bath of metal for 1¼ hrs. results in a loss of approximately 0.10 per cent. of this element.

Phosphorus and Sulphur.—No alteration of phosphorus content has been detected when melting swarf in this manner and likewise with sulphur.

Overall Melting Loss.—No melting loss has been found other than the carbon loss already described. The metal is not normally weighed out of the furnace but, on occasions when the total weight cast has been checked, the loss was nil.

Metal Temperature.—Any desired metal temperature may be obtained. If required the metal can be poured far hotter than is possible with cupola melting, but excessive superheating means greater wear on the furnace lining and roof, and as soon as the metal is hot enough for the castings required, it should be poured.

Metal Cleanliness.—The metal from the electric furnace is noticeably cleaner than cupola metal and when molten in the ladle it is practically free from slag globules.

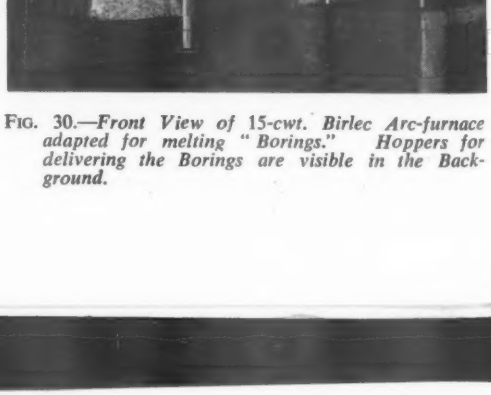

FIG. 30.—*Front View of 15-cwt. Birlec Arc-furnace adapted for melting "Borings." Hoppers for delivering the Borings are visible in the Background.*

Control

Modern methods of production require modern methods of quality control and this has led to the several firms of the group having up-to-date, well-equipped laboratories for the testing of incoming raw materials and the controlling of works processes. Although these laboratories cover general works requirements such as testing of steel supplies and various incoming materials as well as the control of heat-treatment and other works processes, etc., their major function is in carrying out these services in the foundries. The value of this has been proved in the recent years, when the type of raw materials which had been used as a matter of course up to 1939 were either not available or very scarce and substitutes had to be found. Equipment includes chemical laboratories, full metallographic apparatus, the usual physical-testing machines for tensile, transverse, impact and hardness, together with sand-testing apparatus, including experimental sand mills.

The compositions of all pig-iron supplies are checked and tests are carried out also on incoming scrap, coke, etc., to provide the basis for computing cupola mixes. Regular analyses are taken of the metal produced from each melting unit and, in the case of metal supplies to mechanized moulding plants, the practice is for this to be done at least hourly.

Conclusion

In closing this Paper, the Author is aware of many shortcomings due to the limited space available for such a very large subject, but is hopeful that many things left unsaid will be brought out in the discussion. In conclusion, he wishes to acknowledge his thanks and appreciation to the Board of directors of Textile Machinery Makers, Limited, for their permission to present the Paper; to the directors of the associated companies of the Group for the facilities extended in the various foundries; to the foundry managers' and metallurgists' committee for assistance, guidance and criticism in preparing the script, and to the photographic department for the supply of illustrations.

Census of Production Statistics

The following table, taken from the Report on the Census of Production for 1950, Vol. 3, "Metal Manufacture and Vehicles," gives particulars for the ironfounding industry of this country and figures taken from previous census returns (see also page 251 of this issue).

TABLE I.—*Ironfoundries Trade.*

	Unit.	1950.				1949.	1948.	1935.
		England.	Wales.	Scotland.	United Kingdom.	United Kingdom.	Great Britain.	United Kingdom.
Establishments employing on average more than ten persons	No.	768	35	105	908*	915†	870	857†
Total value of sales	£000	113,984	5,556	17,813	137,354	126,123	112,652	—
Total amount charged to customers for work done	,,						1,450	—
Stocks of finished goods produced for sale and work in progress—								
At beginning of year	,,	6,618	324	963	7,905	7,716	6,184	—
At end of year	,,	7,289	276	965	8,530	8,247	7,659	—
Payment for transport by other firms	,,	2,801	89	492	3,382	2,735	2,210	—
Gross output (production)	,,	111,853	5,420	17,324	134,597	123,919	113,366	39,418
Purchases of materials and fuel	,,	49,970	2,972	7,150	60,092	53,604	46,940	—
Stocks of materials and fuel—								
At beginning of year	,,	7,062	431	1,255	8,748	8,162	6,570	—
At end of year	,,	7,549	482	1,301	9,332	8,688	8,050	—
Cost of materials and fuel used	,,	49,483	2,921	7,105	59,509	53,079	45,468	16,121
Payment for work done on materials given out	,,	1,005	81	225	1,311	1,069	1,048	205
Net output	,,	61,365	2,418	9,995	73,778	69,771	66,850	23,092
Average number employed—								
Operatives	No.	87,240	4,233	15,784	107,257	106,836	104,226	100,203
Other workers	,,	12,528	558	2,460	15,546	15,150	14,544	10,539
Working proprietors	,,	124	10	31	165	195	172	
Total employment including working proprietors	,,	99,892	4,801	18,275	122,968	122,181	118,942	110,742
Net output per person employed	£	614	504	547	600	571	562	209
Wages and salaries—								
Of operatives	£000	32,488	1,456	5,408	39,352	37,593	34,965	—
Of other workers	,,	6,094	237	1,038	7,369	6,935	6,314	—
Employers' share of all National Insurance contributions	,,	1,004	51	183	1,238	1,231	954	—
Outworkers: average number employed	No.	29	—	—	29	41	30	—
Payments to outworkers	£000	2	—	—	2	3	2	—
Firms employing on average ten or fewer:								
Number of returns	No.	143	7	11	161	197	195	—
Average number employed (including working proprietors)	,,	924	50	80	1,054	1,270	1,269	—
All firms (including those not making satisfactory returns): estimated average employment	,,	100,965	4,865	18,355	124,185	123,592	120,611	—

* Owing to the risk of disclosure of information relating to individual firms, particulars for establishments in Northern Ireland employing on average more than ten persons cannot be given separately and have been included with those for England. The proportion of the net output of the United Kingdom recorded in Northern Ireland was negligible.

† The particulars shown for 1935 include establishments mainly engaged in manufacturing steel castings. In that year, iron and steel foundries were classified together and, as the firms were not required to give separate details of all steel castings made, it has not been possible to reclassify their returns.

Ultrasonic Methods of Inspection

(*Continued from page* 264)

Assessment of Oscillograms

The difficulties of interpretation brought about by the phenomena described do not normally interfere too much with testing objects of simple shape, and ultrasonic testing is nowadays being applied successfully to such things as ingots, rolls, turbine rotors, shafts and railway axles. Where small miscellaneous castings are concerned, however, the complications described become more formidable and often prohibit any but highly-specialized techniques. One of the chief difficulties connected with testing small castings is that defects are likely to occur in such places where one would obtain a reflection anyway, even if the casting were sound, that is, places such as changes of section and corners. An illustration of this is shown in Fig. 8. Even a comparatively simple item such as a crankshaft can give rise to trouble. Testing from (B) in order to show shrinkage in the web/journal junction would not be practicable, since an echo would in any case be obtained from the opposite face of the web. It is, therefore, better to test from point (A), but the distance from face (A) to the boundary is not much different from that between (A) and the defect, and consequently the echoes tend to become confused. A shrinkage cavity in the eccentric could not be distinguished from the boundary echo which would be given when testing from (C), but a transverse exploration from face (D) would enable one to pick out a defect as indicated.

Castings such as valves and other steam-pressure jobs, being even more complicated, are really out of the scope of ultrasonics, but, where repetition work is being undertaken, it is sometimes possible to make comparative tests using a sound casting as a standard. Differences in the general pattern of the numerous deflections on the screen can often be ascribed to certain defects. Generally, however, ultrasonics should not be used where, for instance, radiography is more easily applied, but rather should be adopted as an inspection method to complement radiography.

Recent Developments

Since the appearance of the first British ultrasonic flaw-detector, others have found their way on to the market, most of which incorporate novel devices such as recording cameras, the instrument marketed by Solus-Schall, Limited, being an interesting innovation. This does not make use of an oscillator for driving the crystal, which is shocked into vibration by the application of a "square-wave" impulse, a change of frequency being easily effected by changing the crystal for one of different thickness, which will resonate at its own particular natural frequency. This instrument uses the single-probe principle, which makes it very easy to handle.

Recently introduced is the C. N. Smyth equipment[4]; this consists of an ultrasonic generator and amplifier designed to be used with an existing oscilloscope. Since a commercial oscilloscope can be used, the apparatus is inexpensive. The probe consists of two semi-circular crystals mounted side by side in a common holder, one receiving and one sending. The probe is therefore a single unit and easy to handle. Owing to the close proximity of the two crystals, wedges are not required for working at short distances from the surface. Defects lying only $\frac{1}{4}$ in. below the surface are readily picked up. The directional characteristics of this probe are very good and enable very accurate location of defects.

REFERENCES

[1] German Patent 569598, February 4, 1933.
[2] U.S. Patent 2280226, April, 1942.
[3] Kelvin & Hughes, Limited, 2, Caxton Street, London, S.W.1.
[4] C. N. Smyth, consulting engineer, 62, Rochester Place, London, N.W.1.

Personal

THE LONDON ALUMINIUM COMPANY, LIMITED, announces that Mr. F. P. Webster has been appointed managing director.

HIGGS MOTORS, LIMITED, announce that MR. A. C. J. LOAT has joined their London sales staff as technical engineer and will be responsible for districts to the south of the Thames.

MR. J. L. GASKELL, chief electrical engineer of the Appleby-Frodingham Steel Company (branch of the United Steel Companies, Limited), Scunthorpe, has been appointed a member of the Yorkshire Electricity Consultative Council.

MR. MAURICE ROBERTS, B.SC., A.I.M., M.I.B.F., has been appointed assistant general manager and metallurgist, Great Bridge Foundry Company, Limited. Prior to this appointment he was on the staff of Vowles Bros., Limited, West Bromwich.

ON THE OCCASION of his seventieth birthday, last Friday, Mr. Horace Green, managing director of Horace Green & Company, Limited, dynamo manufacturers, Station Mills, Cononley, near Keighley, was presented with an easy chair from the employees.

MR. G. MARTIN, B.SC., now working with John Gardom & Company, consulting engineers, of Ripley, near Derby, has been awarded the Degree of Doctor of Philosophy in Industrial Metallurgy at Birmingham University for his research work on "Gating and Heat Flow of Castings."

MR. E. B. WALKER, technical director of Walker Bros. (Wigan), Limited, engineers and ironfounders, has retired from the board of the company owing to ill-health. Mr. Walker, who is now 69, joined the firm in 1903 as an apprentice; he had completed 50 years' unbroken service. He was appointed a director in 1920 and technical director in 1943. His particular interest was the design and supply of large ventilating plant for mines and tunnels.

MR. JOHN C. ROCHE is leaving at the end of August for West Africa to take up the post of Senior Lecturer in Commerce in the Fourah Bay College (University of Durham), Freetown, Sierra Leone. From 1949 until this year he was senior assistant in management studies at the Burton-on-Trent Technical College. Before going to Burton, he was secretary of the Constructional Engineering Company and a director of E. Tallis & Sons, and was a founder member of the Birmingham branch of the Institute of Export.

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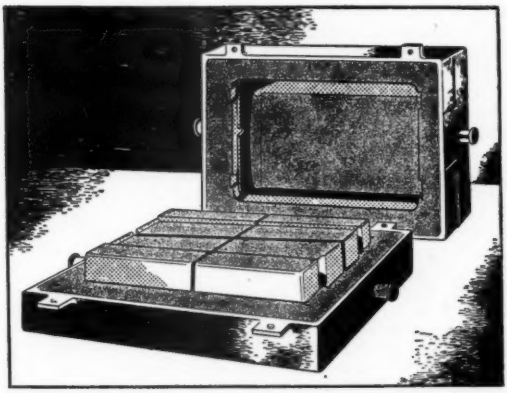

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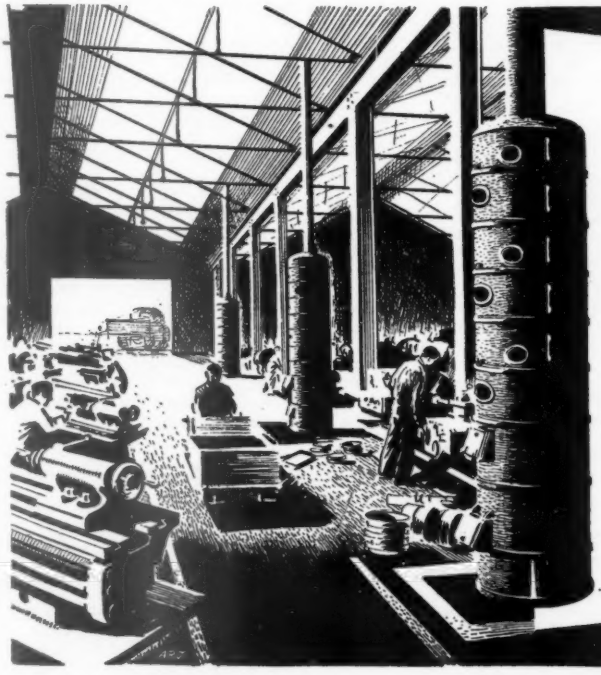

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ST 35

News in Brief

ACTIVE MEMBERSHIP of the American Foundrymen's Society was, at June 18, 11,151.

THE MASSEY HARRIS COMPANY and the Harry Ferguson Companies are proposing to amalgamate.

GUEST & CHRIMES, LIMITED, have prepared plans to extend their iron foundry at Don Street, Rotherham, Yorks.

NEWBY & SON (IRONFOUNDERS), LIMITED, has submitted plans to extend the foundry in Loveday Street, West Bromwich.

A CONTRACT for the construction of the second part of the Catalgzi (Turkey) power station, valued at £3,500,000, has been placed with Metropolitan-Vickers Electrical Company, Limited.

THE INSTITUTION OF METALLURGISTS has announced that the Duke of Edinburgh has consented to open its Platinum Metals Exhibition at Grosvenor House, London, S.W.1, on October 19.

AN ELECTRICAL FAULT is believed to have caused the fire which gutted one building and damaged others on the premises of Edwards & Jones, Limited, ironfounders, of Longton, Stoke-on-Trent.

LETTERS OF OFFER and forms of acceptance in connection with the proposal by the British Motor Corporation, Limited, to acquire the ordinary stock of Fisher & Ludlow, Limited, manufacturers of metal pressings, etc., of Birmingham, were posted this week, it is understood.

BRITISH FIRMS are exhibiting products at the Leipzig Fair, from August 30 to September 9, and those with large stands include the General Electric Company, Thos. W. Ward, Limited; Ruston & Hornsby, Limited; Marshall Sons & Company, Limited; and Hugh Wood & Company, Limited.

THE FIRM'S ACTIVITIES, accident prevention, conditions of employment, trade unionism, research, and craftsmanship have been included in the first experimental three-day course for apprentices about to join the Consett Iron Company, Limited. Similar courses are to be held twice yearly.

OVER A HUNDRED GUESTS assembled at an informal cocktail party held at the Savoy Hotel, London, last week, to greet Mr. Guy J. Coffey, president of the Chicago Pneumatic Tool Company of New York, and chairman of the Consolidated Pneumatic Tool Company, Limited, London, and Fraserburgh.

THE NEXT CONGRESS of the *Bureau International de la Récupération* (B.I.R.) is to be held in London, September 24 and 25. The whole of Thursday, September 24, will be devoted to meetings of the Scrap Iron and Steel Section. There is to be a dinner-dance on the Friday evening, offered by the two affiliated British federations to the foreign delegates.

SINCE 1951, German engineering exports have increased faster than those of the United Kingdom or the United States. In the current monthly "Bulletin for Industry" issued by the Treasury an analysis of engineering exports is given, which also reveals that the U.K. has lost some ground since 1951 to the U.S. and Germany, which are the main competitors in this field.

THE ARGENTINE CENTRAL BANK has granted import licences totalling 220,000,000 pesos for goods from Britain, Japan, Italy, Switzerland, Germany, Brazil, Sweden, Austria, France, Norway, Finland and the U.S.A. The goods include refractory materials, electrical wire and equipment, non-ferrous metals, spares for industrial machinery, industrial chemicals, abrasives, and timber.

SIAM STEVEDORING COMPANY, LIMITED, Bankok, Thailand, wishes to obtain an agency for a U.K. manufacturer of small pumps. Interested manufacturers should communicate with the Bankok company direct, and are requested at the same time to notify the Board of Trade, Export Services Branch, Lacon House, Theobalds Road, London, W.C.1 (reference, E.S.B./1278/53), of any action taken.

IN THE SOUTH AFRICAN HOUSE OF ASSEMBLY, recently, Mr. Paul Sauer, Minister of Transport, warned British locomotive manufacturers that the Government took a serious view of the delay in deliveries of locomotives essential in the railways' re-equipment programme. Delivery of 40 electric locomotives was so much behind schedule that it was at barely half the promised rate, and only three out of 100 steam locomotives had been received.

CRITICISMS of the shortage of steel plate supplies have been made by Sir Frederick Rebbeck, chairman and managing director of Harland & Wolff, Limited. Speaking at a luncheon after the launch of the Rathlin Head, a 7,350-ton cargo liner, for the Ulster Steamship Company, he described the steel situation as "a shocking state of affairs." There would not be a plate in Belfast with which to lay the keel for another ship on the slipway from which the launch took place until next January.

THE URGENT NEED for a testing establishment for machinery, ropes, etc., was pointed out in the National Coal Board's report for 1952. The Board has now decided to set up a central engineering establishment with two main functions: the development of new machinery and equipment, and the testing of machinery, ropes, new materials, and so on. It is understood that the Board is seeking the permission of the Derbyshire County Council to set up the establishment at Stanhope, Bretby, in South Derbyshire.

THE WEAR SHIPBUILDERS' ASSOCIATION, whose headquarters is at Sunderland, celebrates its centenary this year. When the organization was formed there were about 45 shipbuilding concerns on the River Wear, and in 1853, 152 ships of 68,479 tons were launched. In those days vessels of 400 to 500 tons were considered big ships, but to-day the Wear has facilities for building ships up to 26,000 tons. There are now only eight shipyards on the river, but last year they launched 26 ships of more than 170,000 gross tons.

MR. A. L. TOYE, personnel manager of the B.S.A. Company, Limited, Small Heath, Birmingham, addressed a group of French, Italian, and Spanish engineering students visiting the factory on August 18. The students were visiting the works under the auspices of the *Voyages d'Etudes Sociales*, a Paris organization. After touring the works, the students heard short lectures on various aspects of the company's organization. On August 19, the party visited the Dunlop Rubber Company. It is the first time a party from *Voyages d'Etudes Sociales* has visited Britain; last year a party toured Sweden and others have been to Switzerland and Germany.

ALUMINIUM IN AGRICULTURE is one of the subjects on which a paper will be presented during the winter session of the West Midlands Centre of the Institution of British Agricultural Engineers. In less than two years, membership of the Centre has doubled, and this fact, in the opinion of the chairman, is a further recognition of the need for a professional institution to stimulate thought and technical progress. Officers of the Centre elected for the current year are:—Chairman, Mr. A. B. Lees (Harry Ferguson, Limited); vice-chairman, Mr. G. T. Merryweather (Goodyear, Limited); hon. treasurer, Mr. D. B. Purchas (Harry Ferguson, Limited); hon. secretary, Mr. W. Hall (Hart Agricultural Engineering Company, Limited).

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Raw Material Markets

Iron and Steel

Business in the foundries is at the lower level which has been ruling for some time, and holiday influences help to subdue the state of trade. The light and textile foundries and many of the jobbing foundries continue their efforts to secure additional business, but it is difficult in many instances to book sufficient work to maintain production at present levels, and outputs are much below capacity, particularly at the mechanized foundries.

Many inquiries for castings are being circulated, but the tonnage is small and orders booked are readily completed. Forward buying is negligible. For this, as well as for financial reasons, the light foundries are content to buy only sufficient high-phosphorus pig-iron to meet their immediate requirements, and do not consider it necessary or desirable to add to their stocks.

Producers are finding it increasingly difficult to dispose of their makes, and stocks at the furnaces are at a higher level than they have been for some considerable time. Fortunately, this position is only applicable to the high-phosphorus foundry irons, as makers of the low- and medium-phosphorus grades and of hematite have little difficulty in disposing of all available supplies to the engineering and speciality foundries, which generally are employed on a much better scale. The supply of these grades is not in excess of present needs. Home-produced hematite, particularly in the higher silicon ranges, is scarce, and has to be augmented by consignments from abroad to foundries in some areas. As at least three-quarters of the present production of pig-iron finds its way to the steelworks, producers are not unduly incommoded by the reduced demands from foundries.

Many refined-iron makers could undertake additional business, although the shortage of hematite has increased the demands from some producers.

The foundries appear to have adequate supplies of scrap, and coke, ganister, limestone, and firebricks can be acquired in sufficient quantities.

It is an indication of the strange distortions of the steel trade, that although British steel production has been raised to unprecedented heights, several big consignments of billets and slabs have arrived from Australia to meet the needs of the re-rolling industry. These are understood to be of special quality and will enable the bar re-rollers to cater more extensively for the needs of home and foreign buyers who require material superior to the cheaper Thomas steel products offered by Continental makers.

Except for steel plates the acute phase of the finished-steel shortage has ended. So far as can be judged at present, the autumn requirements of the heavy industries promise to be substantial, but impetus is lacking in the export trade. Home consumers no longer find it necessary to send out specifications far in advance of required delivery dates and makers have made considerable progress in overtaking their backlogs.

Plates, however, are in a category apart. The mills cannot cope with the rush of orders, particularly for plates of ¾ in. and under. Thus, the services of the new voluntary organization which is to control distribution will be useful if only to save the rollers from the embarrassments of discrimination. Substantial export orders are in hand for galvanized sheets and in the home market slightly more interest in light sheets is developing. Extensive bookings are also in hand for heavy sections, joists, and channels, but rather easier conditions have developed in the oversea demand for steel rails.

Non-ferrous Metals

In view of the improved situation in Northern Rhodesia, where it seems that, after all, no strike is likely to take place on the Copperbelt, at any rate at the present time, the price of copper in London has been easier. Business has been quiet, however, most of the time, most of the trading being again done in forward metal. In the United States the chief Custom smelter, which, on the eve of the reopening of the London market, lowered its price to 28½ cents, last week returned to 29 cents, but this had no effect on the quotation in Whittington Avenue. On the contrary, as already mentioned, the trend was easier. Prices of the other metals have fluctuated somewhat.

The Chilean copper situation has come into prominence as a result of a statement covering a survey of the outlook for copper mining in that country. It is known that discussions are afoot between the Chilean and the U.S. Government with a view to arranging a deal for the stockpile and majority opinion believes that this will go through. Upwards of 85,000 short tons may well be involved.

The United States Copper Institute has issued details of copper activity for July, which show that U.S. refined copper output was 112,870 short tons, compared with 124,480 tons in June. Outside the United States the corresponding figures were 84,150 tons and 104,135 tons. Production of blister copper in the U.S.A. was 89,000 tons and outside 127,800 tons, the corresponding figures for June being 84,950 tons and 133,240 tons. Deliveries to American fabricators dropped sharply from 139,520 tons to 104,595 tons, while outside the U.S.A. the June figure of 68,130 tons, compared with 74,200 tons in June. Stocks of refined copper in the States at July 31 were 77,100, an increase of about 19,000 tons, while outside the corresponding figures were 166,305 tons and 154,835 tons. It will be noted that there was an all-round falling away in activity, which is not surprising in view of the holiday season.

Official metal prices were as follow:—

COPPER, Standard.—Cash: August 20, £230 to £235; August 21, £230 to £235; August 24, £227 10s. to £230; August 25, £217 10s. to £220; August 26, £222 10s. to £227 10s.

Three Months: August 20, £215 10s. to £216 10s.; August 21, £214 to £214 10s.; August 24, £215 to £216; August 25, £206 to £207; August 26, £209 to £210.

TIN, Standard.—*Cash:* August 20, £610 to £612 10s.; August 21, £587 10s. to £590; August 24, £600 to £602 10s.; August 25, £607 10s. to £610; August 26, £610 to £615.

Three Months: August 20, £605 to £607 10s.; August 21, £587 10s. to £590; August 24, £600 to £602 10s.; August 25, £602 10s. to £605; August 26, £606 to £606 10s.

ZINC.—*August:* August 20, £72 5s. to £72 7s. 6d.; August 21, £72 10s. to £72 12s. 6d.; August 24, £72 5s. to £72 10s.; August 25, £71 5s. to £71 10s.; August 26, £71 15s. to £72.

November: August 20, £72 5s. to £72 7s. 6d.; August 21, £72 10s. to £72 15s.; August 24, £72 7s. 6d. to £72 10s.; August 25, £71 10s. to £71 12s. 6d.; August 26, £71 17s. 6d. to £72.

LEAD.—*August:* August 20, £95 to £95 10s.; August 21, £95 10s. to £95 15s.; August 24, £95 10s. to £96; August 25, £95 15s. to £96 5s.; August 26, £96 7s. 6d. to £96 10s.

November: August 20, £88 15s. to £89 5s.; August 21, £89 15s. to £90; August 24, £89 15s. to £90; August 25, £90 to £90 5s.; August 26, £90 10s. to £91.